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Open Science

Open Science Philosophy

Open science encompasses unrestricted access to scientific research articles, access to data from public research, and collaborative research enabled by information and communication technology tools, models, and incentives. Broadening access to scientific research publications and data is at the heart of open science. The objective of open science is to make research outputs and its potential benefits available to the entire world and in the hands of as many as possible:

- Open science promotes a more accurate verification of scientific research results. Scientific inquiry and discovery can be sped up by combining the tools of science and information technologies. Open science will benefit society and researchers by providing faster, easier, and more efficient availability of research outputs.
- Open science reduces duplication in collecting, creating, transferring, and re-using scientific material.
- Open science increases productivity in an era of tight budgets.
- Open science results in great innovation potential and increased consumer choice from public research.
- Open science promotes public trust in science. Greater citizen engagement leads to active participation in scientific experiments and data collection.

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Open Society

An open society allows individuals to change their roles and to benefit from corresponding changes in status. Open science depends to a greater or lesser extent on digital technologies and innovations in structural processes by an open society. When realized, open science research and innovation can create investment opportunities for new and better products and services and therefore increase competitiveness and employment. Open science research and innovation is a key component of thematic open science priorities. Central to the open science digital infrastructure is enabling industry to benefit from digital technology and to underpin scientific advances through the development of an open society. Open science research and innovation can also contribute to society as a global actor because scientific relations can flourish even where global relations are strained. Open science has a critical role across many areas of decision making in providing evidence that helps understand the risks and benefits of different open science choices. Digital technology is making the conduct of open science and innovation more collaborative, more global, and more open to global citizens. Open society must embrace these changes and reinforce its position as the leading power for science, for new ideas, and for investing sustainably in the future.

It is apparent in open society that the way science works is fundamentally changing, and an equally significant transformation is taking place in how organizations and societies innovate. The advent of digital technology is making research and innovation more open, collaborative, and global. These exchanges are leading open society to develop open science and to set goals for research and innovation priority. Open science goals are materializing in the development of scientific research and innovation platforms and greater acceptance of scientific data generated by open science research. Open science research and innovation do not need help from open society to come up with great ideas, but the level of success ideas ultimately reach is undoubtedly influenced by regulation, financing, public support, and market access. Open society is playing a crucial role in improving all these success factors.

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Open science represents a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and collaborative tools. These innovations capture a systemic change to the way science and research have been carried out for the last fifty years. Science is shifting from the standard practice of publishing research results in scientific publications after the research and reviews are completed. The shift is towards sharing and using all available knowledge at an earlier stage in the research process. Open science is to science what digital technology is to social and economic transactions: allowing end users to be producers of ideas, relations, and services and in doing so, enabling new working models, new social relationships and leading to a new modus operandi for science. Open science is as important and disruptive as e-commerce has been for the retail industry. Just like e-commerce, the open science research paradigm shift affects the whole business cycle of doing science and research. From the selection of research subjects to the carrying out of research, to its use and re-use, to the role of universities, and that of publishers are all dramatically changed. Just as the internet and globalization have profoundly changed the way we do business, interact socially, consume culture, and buy goods, these changes are now profoundly impacting how one does research and science.

The discussion on broadening the footprint of science and on novel ways to produce and spread knowledge gradually evolved from two global trends: Open Access and Open Source. The former refers to online, peer-reviewed scholarly outputs, which are free to read, with limited or no copyright and licensing restrictions, while open source refers to software created without any proprietary restriction and which can be accessed and freely used. Although open access became primarily associated with a particular publishing

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or scientific dissemination practice, open access already sought to induce a broader practice that includes the general re-use of all kinds of research products, not just publications or data. It is only more recently that open science has coalesced into the concept of a transformed scientific practice, shifting the focus of researchers' activity from publishing as fast as possible to sharing knowledge as early as possible. Open science is defined as the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process. As a result, the way science is done in the future will look significantly different from the way it is done now. Open science is the ongoing evolution in the modus operandi of doing research and organizing science. This evolution is enabled by digital technology and is driven by both the globalization of the scientific community and increasing public demand to address the societal challenges of our times. Open science entails the ongoing transitions in the way research is performed, researchers collaborate, knowledge is shared, and science is organized.

Open science impacts the entire research cycle, from the inception of research to its publication, and on how this cycle is organized. The outer circle reflects the new interconnected nature of open science, while the inner circle shows the entire scientific process, from the conceptualization of research ideas to publishing. Each step in the scientific process is linked to ongoing changes brought about by open science, including the emergence of alternative systems to establish a scientific reputation; changes in the way quality and impact of research are evaluated; the growing use of scientific blogs; open annotation; and open access to data and publications. All institutions involved in science are affected, including research organizations, research councils, and funding bodies. The trends are irreversible, and they have already grown well beyond individual projects. These changes predominantly result from a bottom-up process driven by a growing number of researchers who increasingly employ social media in their research and initiate globally coordinated research projects while sharing results at an early stage in the research process.

Open science is encompassed in five schools of thought:

- the infrastructure school, concerned with technological architecture
- the public school, concerned with the accessibility of knowledge creation
- the measurement school, concerned with alternative impact assessment
- the democratic school, concerned with access to knowledge
- the pragmatic school, concerned with collaborative research

According to the measurement school, the reputation and evaluation of individual researchers are still mainly based on citation-based metrics. The h-index is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar. The impact factor is a measure reflecting the average number of citations to articles published in an academic journal and is used as a proxy for the relative importance of a journal.

Numerous criticisms have been made of citation-based metrics, primarily when used, and often misused, to assess the performance of individual researchers. These metrics:

- are often not applicable at the individual level
- do not take into account the broader social and economic function of scientific research
- are not adapted to the increased scale of research
- cannot recognize new types of work that researchers are performing

Web-based metrics for measuring research output, popularized as altmetrics, have recently received much attention: some measure the impact at the article level, others make it possible to assess the many outcomes of research in addition to the number of scientific articles and references. The current reputation and evaluation system has to adapt to the new dynamics of open science and acknowledge and incentivize

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engagement in open science. Researchers engaging in open science have growing expectations that their work, including intermediate products such as research data, will be better rewarded or taken into account in their career development. Vice-versa, the use, and reuse of open data will require appropriate codes of conduct requiring, for example, the proper acknowledgment of the original creator of the data.

These ongoing changes are progressively transforming scientific practices with innovative tools to facilitate communication, collaboration, and data analysis. Researchers that increasingly work together to create knowledge can employ online tools and create a shared space where creative conversation and collaboration can occur. As a result, the problem-solving process can be faster, and the range of problems that can be solved can be expanded. The ecosystem underpinning open science is evolving very rapidly. Social network platforms for researchers already attract millions of users and are being used to begin and validate more research projects.

Furthermore, the trends towards open access are redefining the framework conditions for science and thus have an impact on how open innovation is produced by encouraging a more dynamic circulation of knowledge. It can enable more science-based startups to emerge thanks to the exploitation of openly accessible research results. Open science, however, does not mean free science. It is essential to ensure that intellectual property is protected before making knowledge publicly available in order to subsequently attract investments that can help translate research results into innovation. If this is taken into account, fuller and broader access to scientific publications and research data can help to accelerate innovation. Investments that boost research and innovation in open science would benefit society with fewer barriers to knowledge transfer, open access to scientific research, and greater mobility of researchers. In this context, open access can help overcome the barriers that innovative organizations face in accessing the results of research funded by the public.

Open innovation

An open society is the largest producer of knowledge, but the phenomenon of open science is changing every aspect of the scientific method by becoming more open, inclusive, and interdisciplinary. Ensuring open society is at the forefront of open science means promoting open access to scientific data and publications alongside the highest standards of research integrity. There are few forces in this globe as engaging and unifying as science. The universal language of science maintains open channels of communication globally. Open society can maximize its gains through maintaining its presence at the highest level of scientific endeavor, and by promoting a competitive edge in the knowledge society of the information age. The ideas and initiatives described in this publication can stimulate anyone interested in open science research and innovation. It is designed to encourage debate and lead to new ideas on what and open society should do, should not do, or do differently.

An open society can lead to a research powerhouse; however, open society rarely succeeds in turning research into innovation and in getting research results to the global market. Open society must improve at making the most of its innovation talent, and that is where open innovation comes into play. The basic premise of open innovation is to open up the innovation process to all active players so that knowledge can circulate more freely and be transformed into products and services that create new markets while fostering a stronger culture of entrepreneurship. Open innovation is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation. This original notion of open innovation was primarily based on transferring knowledge, expertise, and even resources from one company or research institution to another. This notion assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they seek to improve their performance. The concept of open innovation is continually evolving and is moving from linear, bilateral transactions and collaborations

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towards dynamic, networked, multi-collaborative innovation ecosystems. This means that a specific innovation can no longer be seen as the result of predefined and isolated innovation activities but rather as the outcome of a complex co-creation process involving knowledge flows across the entire economic and social environment. This co-creation takes place in different parts of the innovation ecosystem and requires knowledge exchange and absorptive capacities from all the actors involved, whether businesses, academia, financial institutions, public authorities, or citizens.

Open innovation is a broad term, which encompasses several different nuances and approaches. Two main elements underpin the most recent conceptions of open innovation: the users are in the spotlight and invention becomes an innovation only if users become a part of the value creation process. Notions such as user innovation emphasize the role of citizens and users in the innovation processes as distributed sources of knowledge. This kind of public engagement is one of the aims of open science research and innovation. The term 'open' in these contexts has also been used as a synonym for 'user-centric'; creating a well-functioning ecosystem that allows co-creation and becomes essential for open innovation. In this ecosystem, relevant stakeholders are collaborating along and across industry and sector-specific value chains to co-create solutions for socio-economic and business challenges. One important element to keep in mind when discussing open innovation is that it cannot be defined in absolutely precise terms. It may be better to think of it as a point on a continuum where there is a range of context-dependent innovation activities at different stages, from research to development through to commercialization, and where some activities are more open than others. Open innovation is gaining momentum thanks to new large-scale trends such as digitalization and the mass participation and collaboration in innovation that it enables. The speed and scale of digitalization are accelerating and transforming the way one designs, develops, and manufactures products, the way one delivers services, and the products and services themselves. It is enabling innovative processes and new ways of doing business, introducing new cross-sector value chains and infrastructures.

Open society must ensure that it capitalizes on the benefits that these developments promise for citizens in terms of tackling societal challenges and boosting business and industry. Drawing on these trends, and with the aim of helping build an open innovation ecosystem in open society, the open society's concept of open innovation is characterized by:

- combining the power of ideas and knowledge from different actors to co-create new products and find solutions to societal needs
- creating shared economic and social value, including a citizen and user-centric approach
- capitalizing on the implications of trends such as digitalization, mass participation, and collaboration

In order to encourage the transition from linear knowledge transfer towards more dynamic knowledge circulation, experts agree that it is essential to create and support an open innovation ecosystem that facilitates the translation of knowledge into socio-economic value. In addition to the formal supply-side elements such as research skills, excellent science, funding and intellectual property management, there is also a need to concentrate on the demand side aspects of knowledge circulation, making sure that scientific work corresponds to the needs of the users and that knowledge is findable, accessible, interpretable and reusable. Open access to research results aims to make science more reliable, efficient, and responsive and is the springboard for increased innovation opportunities, e.g. by enabling more science-based startups to emerge. Prioritizing open science does not, however, automatically ensure that research results and scientific knowledge are commercialized or transformed into socio-economic value. In order for this to happen, open innovation must help to connect and exploit the results of open science and facilitate the faster translation of discoveries into societal use and economic value.

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Collaborations with global partners represent important sources of knowledge circulation. The globalization of research and innovation is not a new phenomenon, but it has intensified in the last decade, particularly in terms of collaborative research, international technology production, and worldwide mobility of researchers and innovative entrepreneurs. Global collaboration plays a significant role both in improving the competitiveness of open innovation ecosystems and in fostering new knowledge production worldwide. It ensures access to a broader set of competencies, resources, and skills wherever they are located, and it yields positive impacts in terms of scientific quality and research results. Collaboration enables global standard-setting, allows global challenges to be tackled more effectively, and facilitates participation in global value chains and new and emerging markets.

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The scholarly research review is a multidimensional evaluation procedure in which standard peer review models can be adapted in line with the ethos of scientific research, including accessible identities between reviewer and author, publishing review reports and enabling greater participation in the peer review process. Scholarly research review methods are employed to maintain standards of quality, improve performance, provide credibility, and determine suitability for publication. *Responsible Peer Review Procedure:* Responsible peer review ensures that scholarly research meets accepted disciplinary standards and ensures the dissemination of only relevant findings, free from bias, unwarranted claims, and unacceptable interpretations. Principles of responsible peer review:

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Numerical Study of Laminar Separation Bubble Over an Airfoil Using SST γ - $Re_{\theta t}$ Turbulence Model on Low Reynolds Number

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Abstract:

A parametric study has been conducted to analyse the flow around S809 airfoil of wind turbine in order to better understand the characteristics and effects of laminar separation bubble (LSB) on aerodynamic design for maximizing wind turbine efficiency. Numerical simulations were performed at low Reynolds number by solving the Unsteady Reynolds Averaged Navier-Stokes (URANS) equations based on C-type structural mesh and using γ - $Re_{\theta t}$ turbulence model. Two-dimensional study was conducted for the chord Reynolds number of 1×10^5 and angles of attack (AoA) between 0 and 20.15 degrees. The simulation results obtained for the aerodynamic coefficients at various angles of attack (AoA) were compared with XFOIL results. A sensitivity study was performed to examine the effects of Reynolds number and free-stream turbulence intensity on the location and length of laminar separation bubble and aerodynamic performances of wind turbine. The results show that increasing the Reynolds number leads to a delay in the laminar separation on the upper surface of the airfoil. The increase in Reynolds number leads to an accelerate transition process and the turbulent reattachment point move closer to the leading edge owing to an earlier reattachment of the turbulent shear layer. This leads to a considerable reduction in the length of the separation bubble as the Reynolds number is increased. The increase of the level of free-stream turbulence intensity leads to a decrease in separation bubble length and an increase the lift coefficient while having negligible effects on the stall angle. When the AoA increased, the bubble on the suction airfoil surface was found to moves upstream to leading edge of the airfoil that causes earlier laminar separation.

Keywords: laminar separation bubble, turbulence intensity, S809 airfoil, transition model, Reynolds number

References

- [1] Lin, J.M., Pauley, L.L., 1996. Low-Reynolds number separation on an airfoil. *AIAA J.* 34, 1570–1577.
- [2] Nakano, T., Fujisawa, N., Oguma, Y., Takagi, Y., Lee, S., 2007. Experimental study on flow and noise characteristics of NACA0018 airfoil. *J. Wind Eng. Ind. Aerodyn.* 95, 511–531.
- [3] Zhang, W., Hain, R., Kähler, C.J., 2008. Scanning PIV investigation of the laminar separation bubble on a SD7003 airfoil. *Exp. Fluids* 45, 725–743.
- [4] M. Gaster, “The structure and behaviour of laminar separation bubbles,” Technical Report 3595, Aeronautical Research Council, 1967.
- [5] H. P. Horton, “Laminar separation bubbles in two and three-dimensional incompressible flow,” Ph.D. thesis, Queen Mary College, 1968.
- [6] M. S. Selig and J. J. Guglielmo, “High-lift low Reynolds number airfoil design,” *J. Aircr.* 34, 72–79 (1997).

- [7] T. J. Mueller and J. D. DeLaurier, "Aerodynamics of small vehicles," *Annu. Rev. Fluid Mech.* 35, 89–111 (2003).
- [8] M. Drela and M. B. Giles, "Viscous-inviscid analysis of transonic and low Reynolds number airfoils," *AIAA J.* 25, 1347–1355 (1987).
- [9] Devinant P, Laverne T, Hureau J. Experimental study of wind-turbine airfoil aerodynamics in high turbulence. *J Wind Eng Ind Aerodynamics.* 2002;90:689–707.
- [10] Rinoie K, Okuno M, Sunada Y. Airfoil stall suppression by use of a bubble burst control plate. *AIAA J* 2009;47:322–30.
- [11] Tani, I., 1969. Boundary-layer transition. *Annu. Rev. Fluid Mech.* 1, 169–196.
- [12] Swift, KM., 2009. An Experimental Analysis of the Laminar Separation Bubble at Low Reynolds Numbers.
- [13] Tani, I., 1961. Critical Survey of Published Theories on the Mechanism of LeadingEdge Stall. Aeronautical Research Institute.
- [14] Katz, J., Plotkin, A., 1991. *Low-Speed Aerodynamics: from Wing Theory to Panel Methods.* McGraw-Hill, Singapore.
- [15] Gaster, M., 1969. The Structure and Behaviour of Laminar Separation Bubbles. HM Stationery Office.
- [16] Bursnall, W.J., Loftin, L.K., 1951. Experimental investigation of localized regions of laminar-boundary-layer separation. National Advisory Committee for Aeronautics.
- [17] B. Abu-Ghannam, R. Shaw, Natural transition of boundary layers - the effects of turbulence, pressure gradient, and flow history, *J. Mech. Eng. Sci.* 22 (5) (1980) 213–228.
- [18] D.D. Pasquale, A. Rona, S.J. Garrett, A selective review of CFD transition models, in: *AIAA Fluid Dynamics Conference*, 2009.
- [19] F. Menter, R. Langtry, S. Volker, Transition modelling for general purpose CFD codes, *Flow Turbul. Combust.* 77 (2006) 277–303.
- [20] Amanullah Choudhry, Maziar Arjomandi, Richard Kelso, A study of long separation bubble on thick airfoils and its consequent effects, *International Journal of Heat and Fluid Flow*, 52 (2015) 84–96
- [21] P.L. Delafin, F. Deniset, J.A. Astolfi, Effect of the laminar separation bubble induced transition on the hydrodynamic performance of a hydrofoil, *European Journal of Mechanics B/Fluids*, 46 (2014) 190–200
- [22] A. Ducoin, J.A. Astolfi, Wall-pressure fluctuations of laminar separation bubble based on direct numerical simulation and experiments over a hydrofoil at $Re = 450,000$, *European Journal of Mechanics / B Fluids*, 76 (2019) 132–144
- [23] Mark S. Istvan. Serhiy Yarusevych, Effects of free-stream turbulence intensity on transition in a laminar separation bubble formed over an airfoil, *Experiments in Fluids* (2018) 59:52
- [24] E. Salimipour, A modification of the k-kL- ω turbulence model for simulation of short and long separation bubbles, *Computers and Fluids*, 181 (2019) 67–76
- [25] Ye Zhang, Zhengzhong Sun, Alexander van Zuijlen and Gerard van Bussel, Numerical simulation of transitional flow on a wind turbine airfoil with RANS-based transition model, *journal of turbulence*, 2017.

Three-Dimensional Numerical Simulation of Hypersonic Flow over a Ramp: Effects of Angle of Attack on Shock Wave Structure

Kalash Dixit

Abstract— It is known that the longitudinal vortex pairs which are known as Görtler vortices are often formed in boundary layers over concave curved surfaces due to the centrifugal instability. The longitudinal vortices can have significant effects on the wall heating rate in hypersonic flow. The purpose of this work is to investigate fundamental characteristics of the Görtler vortices generated on a hypersonic compression ramp surface. In this study, a three-dimensional numerical simulation is conducted at a Mach number of 10.4 using the AUSMDV scheme with the third order MUSCL method, and the LU-ADI implicit method. As a result, the Görtler vortices are generated behind the reattachment point of the boundary layer on the compression ramp and their spanwise wavelength is about three times greater than the boundary layer thickness at the separation point.

Keywords— shock wave/boundary-layer interaction, hypersonic flow, Gortler vortices, ramp.

Minimization of Propagation Delay in Multi UAV Network

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Abstract—Unmanned aerial vehicles (UAVs) are becoming increasingly important in various industrial applications and sectors. Nowadays, a multi UAV network is used for specific types of communication (e.g., military) and monitoring purposes. Therefore, it is critical to reducing propagation delay during communication between UAVs, which is essential in a multi UAV network. This paper presents how the propagation delay between the base station (BS) and the UAVs is reduced using a searching algorithm. Furthermore, the iterative-based K-nearest neighbor (k-NN) algorithm and Travelling Salesmen Problem (TSP) algorithm were utilized to optimize the distance between BS and individual UAV to overcome the problem of propagation delay in multi UAV networks. The simulation results show that this proposed method reduced complexity, improved reliability, and reduced propagation delay in multi UAV networks.

Index Terms—Multi UAV Network, Optimal Distance, Propagation Delay, K - Nearest Neighbor, travelling salesmen problem

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are used in a variety of real-world scenarios, including cargo delivery, traffic monitoring, moving things in potentially risky situations, and surveillance. Many significant firms, such as Google, Qualcomm, Amazon, Ericsson, and Uber, have already begun their plans to perform UAV research and field tests because to the strong demand for UAV applications. UAV can be classified in different types as per altitude and body parts. According to altitude, UAV has classified in two types: 1) High Altitude Platform (HAP) and 2) Low Altitude Platform (LAP). UAV also categorized as per body parts, which are: 1) Rotary wing and 2) Fixed wing [1]. UAVs can be used by two different ways. First, they provide wireless communication by serving as aerial base stations (BSs) by flying high. And second, UAVs can be used as aerial User Equipments (UEs) also known as cellular connected UAVs supported by Ground Users [1]. Motivated by the expansion of usage of UAVs and the increased focus on latency in 5G networks, in this paper, we first give an overview of the delay in multi UAV networks and explain how they can be optimized by real time optimization method as k-Nearest Neighbors (kNN) search algorithm.

A. Literature Survey

Flight time constraints, energy limitations, channel modeling, energy efficient trajectory optimization, latency con-

straints, combined 3D deployment, and other technical difficulties face UAV-enabled wireless networks. Furthermore, new challenges in UAV communication such as completion time minimization [3], energy minimization [4], and throughput maximization [2] can be solved using various optimization techniques such as time discretization, path discretization, block coordinate descent (BCD), successive convex approximation (SCA), and efficient trajectory design. The authors of [3] mentioned a UAV trajectory optimization challenge to reduce the time it takes for a UAV mission to complete, given a specific SNR requirement, the UAV's initial and final locations, and its maximum speed.

The authors suggested heuristic search and Dynamic Programming (DP) methods to satisfy the Requested Timeout (RT) criteria and energy budget in UAV-based communication, and compared them to the traveling salesman problem with time window (TSPTW)[4] [5]. The transmit power can be decreased by using a nonlinear and non convex iterative method to optimize the deployment of more UAVs and decreasing the tolerance of delay, according to the authors of [6].

To save time, an optimization strategy based on collecting point (CP) trajectory planning was accepted. It has been demonstrated that the Age of Information (AoI) algorithm outperforms the Traveling Salesmen Program (TSP) in terms of time minimization [7]. Packet transmission delay minimization problem for a two-layer UAV network was described and addressed by Gradient descent approach using Bisection search algorithm in the design of hierarchical UAV network in Voronoi tessellation[8]. According to [9], the packet size affects the transmission delay; when the packet size increases, the transmission delay increases as well. According to the authors of [10], packet size or block size plays a critical role in latency minimization, reducing transmission time and delay. The completion time for single and multi-UAVs can be reduced by optimizing the hovering places, from where the sensor collects data, and trajectory planning [11]. [12] optimizes the overall spectrum and total power of the UAV network in a multi hop relay system to reduce packet delay.

URLLC (ultra-reliable low latency communications) capacity may be increased with the least amount of bandwidth by extending URLLC transmission time, and latency requirements can be met with repetition-based coding scheme

optimization [13]. It is expected that by optimizing the pilot and block lengths, the transmission delay will be reduced [14]. The optimum error probability of two alternative transmission systems, variable rate transmission and fixed rate transmission, increases the queuing delay but produces identical results in [15].

The Iterative K – Nearest Neighbors (IKNN) Method was presented in [16] as an alternative variant of the k-NN algorithm for very high spatial resolution image classification in UAVs. Experiments in [16] utilizing the proposed technique with a confidence threshold of 60% yielded a proportion correct (PC) of 90%, which was superior to Support Vector Machine (SVM) and simple k-NN methods. The attack detection method is investigated in [17] the Canadian Institute for Cybersecurity Dataset using three data mining algorithms based on particle swarm optimization (PSO), namely PSO-K Nearest Neighbor, PSO-Random Forest, and PSO-Decision Tree (CICIDS2017).

In paper [18], the average performance of the proposed PSO algorithm with a single swarm at 200 iterations for short-range and long-range test situations is 0.93 and 0.92 for short-range and long-range test scenarios, respectively. The performances with 10 swarms (or Drones) become 0.97 and 0.96 while meeting all of the dynamic restrictions. Although research in [19] showed that the efficiency of solving the TSP by the Accelerated Augmented Lagrangian Hopfield Neural Network (AALHNN) diminishes as the number of cities increases, the Hopfield Neural Network (HNN) may not always yield an efficient solution when solving the TSP.

This paper's key contribution is the employment of various strategies to reduce propagation delay. We first determine how propagation delay affects the throughput communication between base station and drone, as well as the inter drone communication network, for multi-UAV networks. Rather than considering only one station for the entire network, we investigated a more realistic scenario in which multiple docking stations are available and the UAV should always consider moving to the nearest station if necessary. The k-Nearest Neighbors (k-NN) Search algorithm and travelling salesmen problem are a meta-heuristic optimization techniques for resolving optimization issues.

The rest of the paper organized as follows: Section II presents the system model and problem formulation. In Section III, the development of k-Nearest Neighbors (k-NN) search algorithm and TSP method also derived. Simulation results and comparison of both methods are given in Section IV. Section V gives conclusion.

II. SYSTEM MODEL AND PROBLEM FORMULATION

A. System Model

According to Figure 1, base station (BS) has communication with other four UAVs and they are interconnected, which means drones are also internally connected to each other. Here, in figure 1 red color indicates that the communication can be possible between interconnected UAVs while blue color

shows that only drones are sending messages to BS and green color explains about UAVs and BS communication. For some application, we can say that if any failure occurred during operation, other UAV replace that faulted UAV and continue their operation.

In general, the total delay can be calculated as summation of transmission delay, queueing delay, processing delay and propagation delay. The time it takes a bit to travel from one end of a link to the other is referred to as propagation delay. The propagation speed (s) of the wave signal and the distance (D) between the transmitter and receiver determine the delay. The propagation delay T_{prop} is the amount of time it takes for a signal change to go from one node to the next over the communication medium. The following equation can be used to compute it.

$$T_{prop} = \frac{D}{s} \quad (1)$$

where, D is the distance between BS to UAV and s is the propagation speed. Here, for simplicity we have considered four UAVs and the distance between BS to UAVs are D_1 , D_2 , D_3 and D_4 . The internal network distance are D_{ij} , which means UAV1 to other UAVs distance are D_{12} , D_{13} and D_{14} and similarly others are also denoted by this variables.

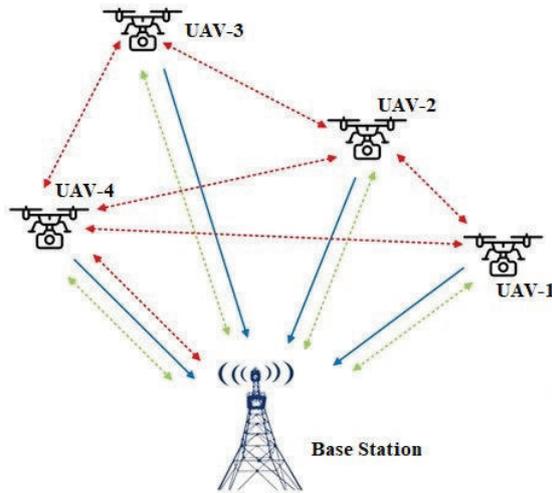


Fig. 1: Multi UAV Network

B. Problem Formulation

Our aim is to minimize propagation delay (T_{prop}) for direct communication with BS and inter UAV for UAV multi hop network. The transmission time of a message relies upon the size of the message and bandwidth of the channel. Here, we have assumed that the other delays between BS to main UAV is avoidable. Now, the total propagation delay has been calculated as follows:

$$T_{Ptotal} = T_{P1} + T_{P2} + T_{P3} + T_{P4} + \dots + T_{Pn} \quad (2)$$

where, $T_{P1}, T_{P2}, T_{P3}, T_{P4}, \dots, T_{Pn}$ are propagation delays from BS to four UAVs. For simplicity, we have assumed there are only four UAVs rather than n number of UAVs. Here, by equation 1, we can say that,

$$\frac{D_{total}}{s_{total}} = \frac{D_1}{s_1} + \frac{D_2}{s_2} + \frac{D_3}{s_3} + \frac{D_4}{s_4} + \dots + \frac{D_n}{s_n} \quad (3)$$

We have assumed that the propagation speeds from transmission of messages from BS to UAVs are similar and unique. so that $s_1 = s_2 = s_3 = s_4 = s_{total} = S$. So that,

$$\frac{D_{total_a}}{S} = \frac{D_1 + D_2 + D_3 + D_4 + \dots + D_n}{S} \quad (4)$$

Equation 3 and 4 represents for the communication between base station to individual UAVs. However, for inter connected UAV network we can say as per follows:

$$D_{total_b} = \sum_{i=1}^n \sum_{j \neq i} \sum_{j=i+1}^n D_{ij} \quad (5)$$

In above equation, for fixed value of i, the total distance can be derived for example, if we have fixed $i = 1$ then we can have distance as D_{12}, D_{13} and D_{14} . Then total distance for inter communication can be calculated as $D_{total} = D_{12} + D_{13} + D_{14}$ and so on.

By above equations 4 and 5, we can say that propagation delay T_{prop} is directly proportional to distance and it is proved that if the distance between drones are increasing then T_{prop} will also increase drastically.

Let us consider that BS transmit the message to all the UAVs but due to longer distance between UAVs and BS, few drones will receive messages after some delay, which is called propagation delay. Now, it is clear that to minimize the propagation delay, the neighbour drones can communicate with each other. For example, BS transmitted the message to UAV3, but it is a long way as compared to other UAVs and that is why, it can receive message from neighbour UAV like UAV2 or UAV4.

However, our problem is that to minimize the propagation delay, we should consider that if any UAV have technical or any other fault then, it should be in the range of BS. By considering above arguments, the optimization problem can be formulated as follows:

$$\begin{aligned} & \min T_{prop} \\ \text{subject to} & \quad D_{min} < D_{ij} \quad (C1) \\ & D_{total} = \sum_{m=1}^n D_m \quad (C2) \end{aligned}$$

Here, the D_{min} is the minimum distance should be possible between UAVs and D_{ij} is distance between interconnected UAV network for example D_{12}, D_{13}, D_{14} and so on.

There are three key reasons why this problem is difficult to solve. First and foremost, the challenge must optimize distance, which varies depending on the application. Second, because the optimization variables for multi-UAV communication scheduling are non-stationary, the defined problem is a constrained optimization problem, an issue that isn't

convex. Third, optimizing minimal distance, hovering, and flying communication scheduling at the same time is tough. The minimum distance between UAVs sometimes mandatory, which means it is dependent on height and hovering speed.

Here, constraints 1 indicate that there should be minimum distance present between interconnected UAVs, which means there is always D_{ij} is higher than the minimum distance. C2 described as according to equation 4. To address this issue, we present an enhanced k-Nearest Neighbors (k-NN) search algorithm and Travelling Salesmen Problem (TSP) method in which the UAVs track each other sequentially and the propagation delay is minimized by locating the nearest neighbor UAV. In the following subsection, we describe how the k-NN algorithm and TSP can be used to find optimal distance and nearest UAV from the BS and intercommunication individual drones.

III. OPTIMIZE DISTANCE BY K-NEAREST NEIGHBORS (K-NN) SEARCH ALGORITHM AND TRAVELLING SALESMEN PROBLEM

A. k-Nearest Neighbors (k-NN) search algorithm

k-Nearest Neighbor is a basic algorithm that maintains all available examples and categorizes fresh data or cases using a similarity measure. It's most commonly used to classify a data point based on the classification of its neighbours. The distance measure between two input data points is used to define similarity. The Euclidean distance approach is a well-known example and also applicable in our application.

The value of k, the euclidean distance, and the normalisation of the parameters are all aspects that influence the performance of k-NN. Here, we have considered the distance from BS to UAVs. Internal distance between UAVs can also be evaluated using the following technique. The following steps are performed to understand the k-NN algorithm:

Input dataset = $\{D_1, D_2, \dots, D_n\}$
 where, D_1, D_2 = distance between BS to individual UAVs. If the distance is between UAVs then it will be D_{12}, D_{13}, D_{14} and so on.

Step:1- Collection of input data as approximate distance of UAVs from BS. Here, the dataset is considered as the input form for next step of algorithm. We have loading the input data to the simulator.

Step:2-Calculate the Euclidean distance between drones using following formula,

$$\sqrt{\sum_{m=1}^n (D_m)^2}$$

For example,

$$\sqrt{(D_1 + D_2 + \dots + D_n)^2}$$

where, D_1, D_2 are the distances between the BS and the individual UAVs. As per figure 1, we can say that the individual distance between BS and UAV have been taken as euclidean distance. To find the k-nearest neighbour drones, for each variable in the dataset, From smallest to greatest, sort the ordered collection of distances and indices.

Step:3-Collect data of nearest assigned drones and store the data.

For tuning and normalize the set, we can assume value of 'k'. The value of 'k' has an impact on the result of the drone nearest dataset. The number of drones that must be considered is determined by the input variable 'k.' The value of 'k' has an impact on the algorithm because it is used to define the dataset limits. The UAV routes are built using the k-NN search method, and the accuracy of the k value is increased. When optimizing by distance, we choose the UAVs with the maximum and minimum distance equation(4).

The conclusion is unclear if the two Nearest Neighbor drones (k=2) belong to two separate classes. As a result, we raise the number of nearest neighbor UAVs to a higher number (eg. 4-nearest neighbour drones). This will establish a closest neighbor region and provide clarity. The simulation results of k-Nearest Neighbors (k-NN) search algorithm is shown in next section.

B. Travelling salesmen problem

The traveling salesman problem, sometimes known as the TSP, is a classic combinatorial optimization problem. The following is a description of the method. If a traveling salesperson needs to visit several cities, he must design a route that satisfies the constraints that every city must be visited once and only once, and the final arrival city must be the departure city in order to ensure the salesman's profit. The ultimate goal of path selection is to choose one that is efficient and has the shortest total length of all the options. The length of the salesman's route is usually determined by the order in which he visits all of the cities.

In our case, we have substituted cities with drones or UAVs as part of a multi-drone network, with the salesman serving as the base station, relaying data to the drones, and the drones' locations defined for the sake of simplicity. The fundamental purpose of the TSP approach is to reduce latency by optimizing the distance between drones.

As per our problem, by optimizing the distance between BS and drones and inter UAV we can easily minimize the propagation delay. Here UAVs are serving the relay links and distance optimization can be done via different algorithms. To maintain UAV's flight height, shorter distance should be maintained in vertical direction. TSP algorithm is very known algorithm to find out the shortest distance between multiple nodes. It is generally used to find out the shortest distance and nearest neighbour target. Here, we have used this algorithm to find out the shortest distance and nearest UAV when the failure of the transmission of the message.

Based on different method, in this paper the TSP method is used to find which is the nearest UAV from main UAV. Assume that due to some technical issue if any UAV will be failed, the communicating UAV find out the nearest UAV and pass on the message for the other inter UAVs.

Algorithm:

Allocate targets: allocate every UAVs to its nearest station

Sort base: sort UAVs by the number of allocated target UAVs while (unvisited target UAVs) do

Select the base with the most target UAVs

Detect target UAVs with Nearest Neighbour UAV

if (unvisited target UAVs in this base) then

Reallocate: allocate the remaining target UAVs to the second nearest UAV

end if

end while

while (bases with the number of UAVs lower than limit) do

Select the base with the least target UAVs and close the UAV

Reallocate: allocate target UAVs of the UAV to the nearest neighbour UAV

Re-detect target UAVs: add the new target UAVs for the neighbour UAV

end while

After implementing TSP algorithm, the minimum distance between UAVs should be cleared and also find the shortest path for the multi hop network. Here, once the distance should be minimized, then the delay between two UAV's transmission will be automatically decreased. TSP algorithm have lower complexity value as compared with other weighted strategies.

IV. SIMULATION RESULTS AND ANALYSIS

In the k-NN algorithm, where k is a positive integer, the categorization of unlabeled data is decided by a constant number of nearest neighbors. The significance of k is that it determines the algorithm's accuracy and effectiveness. We have four UAVs here, and our goal is to minimize the propagation latency by minimizing the distance between them. The fact that the UAV will take longer to process the message if it continues to hover and transmit data. However, because the propagation delay is exactly proportional to the distance between transmitting objects when other interferences are ignored, the distance has an impact on the propagation delay.

Figure 2 shows that each UAV has covered a particular coverage area, and the nearest drone has been tracked using different values of k for the k-NN algorithm. Our estimations become less stable as we reduce the value of k to 1. Inversely, when we increase the amount of k , our estimates grow more stable, making them more likely to be accurate (up to a certain point). We eventually start to see an increase in the amount of errors. After the closest UAV has finished the maximum number of iterations, the next closest UAV takes over and continues training the model, and so on until all of the required iterations have been completed. We used different values of k in our simulation exercise, and it's evident that the various colored dots indicate that drones are hovering within range, it can not exceed their distance between other drones. In an experiment, multiple nearest k values were used to track the precise position of the drone. The graph shows that, as the distance between the BS and the drone increases, the larger the value of propagation delay.

Similarly, the TSP algorithm shows the best and accurate results for the shortest path. Here for the simplicity, we have taken ten number of UAVS but the TSP algorithm can be

applied over more number of UAVs. But as per the research, more number of UAVs also affect the total throughput of the system. The distance between UAVs have taken as an assumptions but if the distance is more than the numbers then also TSP algorithm can solve the shortest path and nearest target UAV problem i.e the path planning issue can be solved by TSP algorithm as in accurate way.

Figure 3 indicates that TSP algorithm can also solve the shortest length problem. The total path length and random location of drones calculates the overall path for interconnected UAV network. By comparing both algorithm it is clear that there is only minor difference of distance calculation between drones.

In the experimental analysis, the number of UAVs has been taken 10 for simplicity. But, here we have compared the results with more number of drones with and also showcase the total path length for TSP and k-NN method.

Similarly, in figure 4 and 5, it is obvious that if the UAV network has less than 10 swarm drones, the system will become more easy to solve using the TSP method; nevertheless, the k-NN approach will produce better results as well as path length also decreased as compared to TSP method.

By figure 6 and 7, it is clear that if the UAV network have more number of swarm drones i.e 30 then the system will get complicated to solve by TSP algorithm, however, k-NN will get better results but path length will get increased.

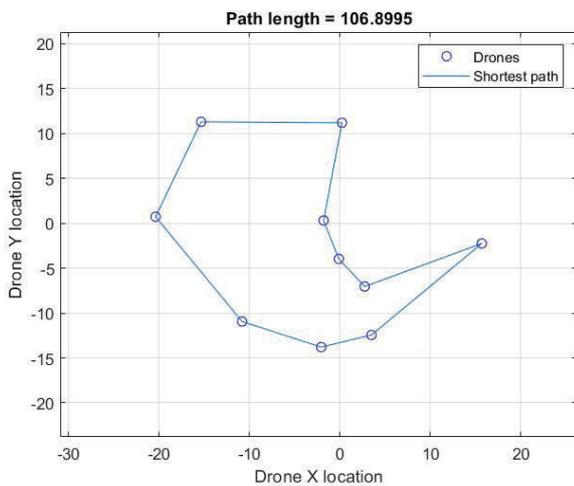


Fig. 2: Simulation Results of k-NN Algorithm (No of UAV=10)

The fundamental disadvantage of k-NN is that it becomes much slower as the volume of input grows, making it an unrealistic solution in situations when predictions must be made quickly. However, because we have a restricted number of UAVs, the k-NN technique is ideal for us.

Furthermore, the estimated optimal solution of the TSP was successfully attained numerous times in the simulation experiment, proving that the extremum obtained by this kNN technique is the ideal solution of the initial issue. When

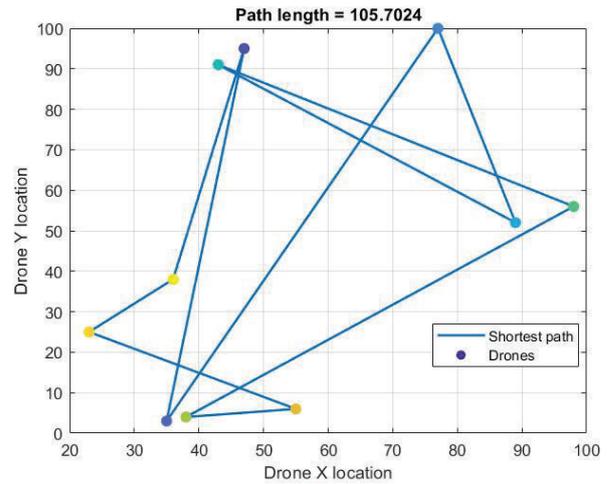


Fig. 3: Simulation Results of TSP method (No of UAV=10)

compared to the standard TSP, the kNN approach can ensure that it is effective for the problem at hand, and the kNN solution obtained is superior.

V. CONCLUSION

The usage of UAVs is increasing day by day in many industrial applications due to their variety of characteristics such as reliability, portability, safety and ease of use, etc. Therefore, effective communication between the BS and UAVs plays a vital role in designing a multi UAV network. This paper presents the usage of the k-NN algorithm and TSP method to calculate the optimal distance between BS and individual UAV. The proposed approach overcomes the propagation delay problem, improving communication between BS and individual UAVs in a multi- UAV network.

REFERENCES

- [1] Mohammad Mozaffari, Walid Saad, Mehdi Bennis, Young-Han Nam, and M'erouane Debbah, "A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems," *IEEE Communications Surveys & Tutorials* Volume: 21, Issue: 3, thirdquarter 2019
- [2] Yong Zeng, Rui Zhang and Teng Joon Lim, "Throughput Maximization for UAV-Enabled Mobile Relaying Systems", *IEEE TRANSACTIONS ON COMMUNICATIONS*, VOL. 64, NO. 12, DECEMBER 2016
- [3] Shuowen Zhang, Yong Zeng and Rui Zhang, "Cellular-Enabled UAV Communication: A Connectivity-Constrained Trajectory Optimization Perspective" *IEEE TRANSACTIONS ON COMMUNICATIONS*, VOL. 67, NO. 3, MARCH 2019
- [4] Rania Islambouli And Sanna Sharafeddine, "Optimized 3D Deployment of UAV-Mounted Cloudlets to Support Latency-Sensitive Services in IoT Networks" *IEEE Access (Volume: 7)* Page(s): 172860 - 172870
- [5] Hieu Tran-Dinh, Thang X. Vu, Symeon Chatzinotas and Bjørn Ottersten, "Energy-efficient Trajectory Design for UAV-enabled Wireless Communications with Latency Constraints" 2019 53rd Asilomar Conference on Signals, Systems, and Computers
- [6] Kanghua Chen, Ying Wang, Zixuan Fei and Xue Wang, "Power Limited Ultra-Reliable and Low-Latency Communication in UAV-Enabled IoT Networks" 2020 *IEEE Wireless Communications and Networking Conference (WCNC)*
- [7] Peng Tong, Juan Liu, Xijun Wang, Bo Bai and Huaiyu Dai, "UAV-Enabled Age-Optimal Data Collection in Wireless Sensor Networks" 2019 *IEEE International Conference on Communications Workshops (ICC Workshops)*

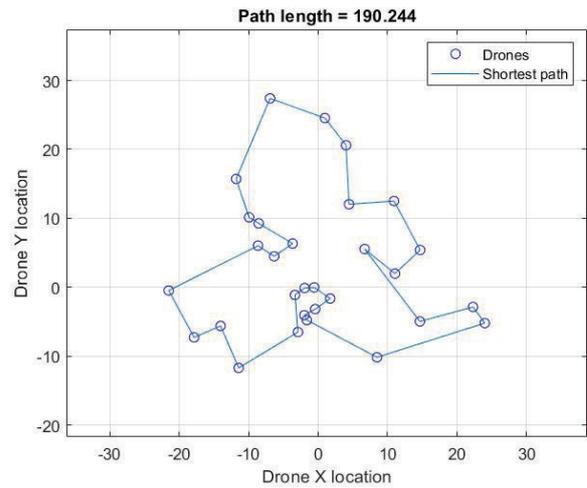
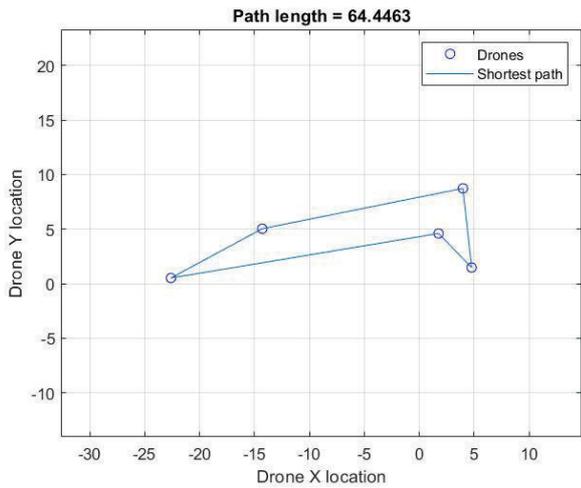


Fig. 4: Simulation Results of k-NN Algorithm (No of UAV=5) Fig. 6: Simulation Results of k-NN Algorithm (No of UAV=30)

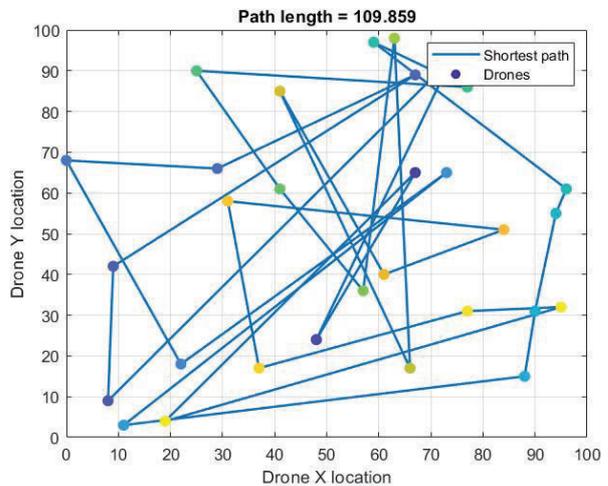
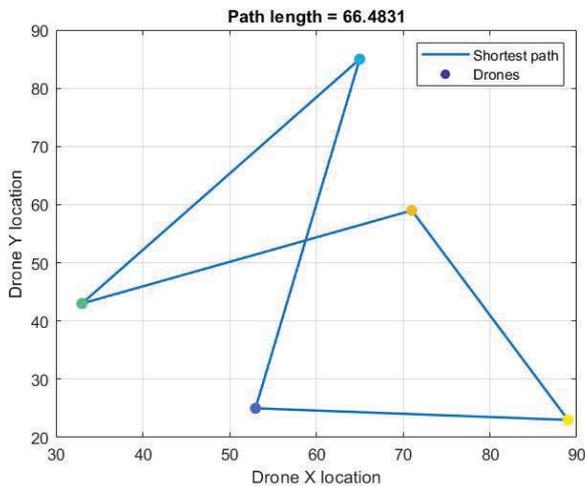


Fig. 5: Simulation Results of TSP method (No of UAV=5) Fig. 7: Simulation Results of TSP method (No of UAV=30)

[8] Jin Li and Youngnam Han, "Optimal Resource Allocation for Packet Delay Minimization in Multi-layer UAV Networks" IEEE Communications Letters (Volume: 21 , Issue: 3 , March 2017)

[9] Xunli Fan and Feifei Du, "An Efficient Bypassing Void Routing Algorithm for Wireless Sensor Network" Hindawi Publishing Corporation Journal of Sensors Volume 2015, Article ID 686809

[10] Murtaza Ahmed Siddiqi, Heejung Yu and Jingon Joung, "5G Ultra-Reliable Low-Latency Communication Implementation Challenges and Operational Issues with IoT Devices" Electronics 2019, 8, 981, This article belongs to the Special Issue IoT in 5G

[11] Zhen Qin, Aijing Li, Chao Dong, Haipeng Dai and Zhengqin Xu, "Completion Time Minimization for Multi-UAV Information Collection via Trajectory Planning" (This article belongs to the Special Issue Optimization and Communication in UAV Networks)

[12] Jin Li and Youngnam Han, "A Traffic Service Scheme for Delay Minimization in Multi-Layer UAV Networks" IEEE Transactions on Vehicular Technology (Volume: 67 , Issue: 6 , June 2018)

[13] Arjun Anand and Gustavo de Veciana, "Resource Allocation and HARQ Optimization for URLLC Traffic in 5G Wireless Networks" IEEE Journal on selected areas in communications, Vol. 36, No. 11, November 2018

[14] Jie Cao, Xu Zhu, Yufei Jiang, Yujie Liu and Fu-Chun Zheng, "Joint Block Length and Pilot Length Optimization for URLLC in the Finite Block Length Regime" 2019 IEEE Global Communications Conference (GLOBECOM)

[15] Deli Qiao , M. Cen Gursoy and Senem Velipasalar, "Throughput-Delay Tradeoffs With Finite Blocklength Coding Over Multiple Coherence Blocks" IEEE transactions on communications, Vol. 67, No. 8, August 2019

[16] Luis Fernando Chimelo Ruiz, Laurindo Antonio Guasselli, Alexandre ten Caten and Daniel Capella Zanotta, "Iterative K – Nearest Neighbors Algorithm (IKNN) for submeter spatial resolution image classification obtained by Unmanned Aerial Vehicle (UAV)" International Journal of Remote Sensing 2018

[17] Sularso Budilaksono, Andri Agung Riyadi, Lukman Azhari, Dedi Dwi Saputra, M. Anno Suwarno, I Gede Agus Suwartane, Jupriyanto, Andika Ramadhan, Agus Prasetyo Utomo, Achmad Fauzi, "Comparison of Data Mining Algorithm: PSO-KNN, PSORF, and PSO-DT to Measure Attack Detection Accuracy Levels on Intrusion Detection System" IOP Conf. Series: Journal of Physics 2020

[18] Jong-Jin Shin and Hyochoong Bang, "UAV Path Planning under Dynamic Threats Using an Improved PSO Algorithm" International Journal of Aerospace Engineering Volume 2020, Article ID 8820284

[19] Yun Hu and Qianqian Duan, "Solving the TSP by the AALHNN algorithm" Mathematical Biosciences and Engineering, Volume 19, Issue 4, 3427-3448.

Modeling Approach for Evaluating Energy Performance of a Large-Scale Housing Stock

Azzam H. Alosaimi

Abstract— The Kingdom of Saudi Arabia (KSA) is located in the middle east and accounts for 80% of the Arabian Peninsula. Its population is 34.2 million persons and growing at 1.7% per year. The KSA economy is developed and had a per capita Gross Domestic Product (GDP) of US\$23,139 in 2019. Its major source of economy is oil produced by burning fossil fuels, and accounting for +90% of the KSA exports revenues, and 40% of the GDP. The KSA's economy was radically changed in 1973 due to global oil crises. This increases worldwide oil demands and resulted in lifting the kingdom's financial limitations. The government has continued to make considerable profits from oil sales, and has invested it in power production, telecommunications, commerce, social development, and infrastructure projects to promote long-term economic growth.

The fundamental source of electricity in the KSA is petroleum and is delivered to the citizens through public networks. Most of the electricity energy demands, +70%, is consumed by the buildings stock, and more than 50% of it is used by the residential stock alone; industrial and commercial sectors are responsible for 18 and 12%, respectively. Most of the residential stock energy is utilized by cooling, especially during summer due to harsh weather conditions. Therefore, this study will develop a tool eligible to evaluate the sensitivity of reducing electricity use, peak energy demands, and CO₂ emission rates of the KSA housing stock through thermal envelope modifications.

Modeling energy performance of a large-scale housing stock is a complex task and requires data validation. It has two major types of modeling approaches; *Top-down* and *Bottom-up*. *Bottom-up* approach was employed to construct the energy baselines and to evaluate variables sensitivity utilizing *Energyplus* software. The results show that the housing stock can reduce about 20-25% of its total energy demands, and around 10-15% of its contribution to carbon emissions.

Keywords— Carbon emissions, Energy demands, Energy efficiency, Greenhouse gas, Sensitivity analysis,

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Evaluation of the Energy Performance of Low Rise Residential Buildings in The Kingdom of Saudi Arabia

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Abstract

The energy demand in Saudi Arabia has been increasing sharply in recent decades, with electricity consumption increasing at a rate of approximately 7% per year. Saudi Arabia faces rapid infrastructure expansion, notably in residential buildings, due to its fast-growing population and high economic growth. Saudi Arabia is characterised by a hot climate, so people tend to use air conditioning extensively to cool indoor spaces, causing electricity bills to increase and the country to spend more on generating electricity. The residential sector consumes almost 50% of the building stock electricity consumption in Saudi Arabia because of its high cooling demand. The overall electricity demand continues to increase by approximately 5–8% annually, which will contribute to oil production and consumption becoming equal in 2035.

The Kingdom of Saudi Arabia (KSA) has taken significant policy steps to promote energy-efficient measures and improve the sustainability of the building sector. The adoption of the Saudi energy conservation code (SBC 602) will help minimise economic costs, as indicated in the country's Vision 2030. For this reason, in line with the global sustainable development goals and following the country's Vision 2030, the aim of this study was to evaluate the impacts of various energy-efficient measures on the energy demand of a prototypical villa in Saudi Arabia.

For the Saudi building industry, this study proposes an approach to identify energy consumption reduction optimisation solutions, which covers the assessment of thermal insulation, reflective coating surfaces, window shading devices, efficient glazing solutions, and roof photovoltaic (PV) systems.

To achieve the aim of this study, a base case model was designed using the computer-based simulation software Integrated Environmental Simulation Virtual Environment (IES-VE). Energy performance was then validated against the actual electricity bill. As a result, this study shows the link between the performance of old housing infrastructures and that of the recently amended Saudi

Building Code (SBC). The present findings show that applying and combining various energy-efficient measures should be considered to obtain significant energy savings.

Aims and Objectives

The primary aim of this research was to evaluate the contribution of thermal envelope improvements to reductions in electricity use, peak energy demands, and their sensitivity to determine the optimised solutions by combining energy-efficient envelope systems in KSA.

This study intends to test the proposed strategies individual of the archetypical building model for villas in KSA for comparison of each modification's contribution to the building envelope.

This study was also aimed at conducting energy modelling and validation of the designed measures for different climatic zones in the KSA.

listed of specific objectives

Objective A: To define the typical housing unit in Saudi Arabia and its typical envelope.

Objective B: Translating Saudi building code (SBC) requirements into a building model to evaluate the performance of the chosen baseline model and additional optimised scenarios.

- To investigate the potential improvements of the building envelope and their impacts on energy efficiency through the adoption of different energy-efficient measures.
- To quantify the contribution of opaque elements to building performance (varying insulation types and thicknesses).
- To investigate the impact of solar radiation on energy efficiency by considering different glazing and shading devices
- To quantify the overall contribution of envelope systems to energy efficiency

Fixed parameters: design and form, climate and location, occupancy, internal gains (lighting, equipment, and appliances), and shading

Objective C: To investigate the impacts of Integration the Saudi Code of Energy Conservation with the PV Systems in Residential Buildings (e.g. a PV roof system with passive design techniques), such as those of increased insulation and efficient glazing and shading devices

Objective D: To identify the best-performing combination of building envelope parameters to improve energy efficiency and to evaluate the building envelope elements that are most sensitive and cost-effective for selected locations.

Objective E: Base case model validation: To validate this study, the energy consumption results will be validated to ensure that the data for the energy simulation model are reliable by comparing the results of the monthly usage simulation for the base case model with the

monthly electricity bill data from the Saudi Electricity Company and with other study data in the literature.

Methodology

The purpose of this study was to evaluate the sensitivity of modifying the thermal envelope and its impact on the reduction of the energy demand in housing units in Saudi Arabia. This study was performed to define suitable and efficient design approaches for Saudi housing using computer simulation tools (IES-VE) on an archetypical baseline building model to evaluate building envelope parameters and their impacts on energy consumption.

In this study, measures were designed to optimise the energy efficiency of residential buildings. However, further investigation will be conducted through a simulation process to identify ways to improve the energy performance of residential buildings in the KSA.

Moreover, simulations were performed in which data were organised and compared with the base case for each energy-efficient measure. This is essential to identify the most useful energy performance measures for building envelopes that take into account the design standards of SBC 602 for energy conservation. Finally, multiple measures were combined to show how energy intake could be prevented by adapting building envelope modifications and other elements assessed in this study.

Research Contributions

The first formal set of Saudi building codes and regulations produced was first released in 2007. Due to the SBC just becoming necessary in 2010, there is a lack of awareness among industry experts and the public. As a result, there are concerns regarding whether the steps implemented will be adequate between old housing infrastructure and recent modifications to building regulations. Therefore, it is recommended to examine building performance and assure compliance with the SBC in the design stage.

The Role of the University Campus in Shaping the Built Environment of Its Local Communities

Lawrence Babatunde Ogunsanya

Abstract— The university has been in existence, in one form or another, for over a thousand years and has contributed in multiple ways to modern society. It is considered a center of culture, aesthetic direction, and moral forces shaping the civilized society. Universities also contribute in important ways to the economic health and physical landscape of neighborhoods and cities, serving as permanent fixtures of the urban economy and the built environment. Due to the size and location of university campuses, they put demands on the urban character, systems, and infrastructure of the neighboring communities. These demands or impacts have substantial implications for the built environment. It is important to understand the impacts university campuses have on their surrounding communities and urban environments because the destiny of the university is inextricably linked to the destiny of the adjacent neighborhoods. This paper identifies the diverse factors generated by universities in shaping the built environments of their local communities within different spatial contexts such as urban, rural, and township regions situated in South Africa. By applying a mixed methods approach in four university campuses within the province of KwaZulu-Natal in South Africa. Several data collection instruments were used, such as in-depth interviews, a survey, remote sensing, and onsite observations. The thematic findings revealed numerous factors which influence the morphology of neighbourhood built environments and the myriad of relationships the university has with its local community. This paper also reveals that the university campus is more than a precinct which accommodates buildings and academic endeavours, the role of the university in this century has changed dramatically from its traditional roots of being an elite enclave of academics to a more inclusive and engaged entity that is concerned about providing relevant holistic solutions to society's current challenges in the built environment.

Keywords— university campus, built environment, architecture, neighborhood planning.

Assessment and Optimisation of Building Services Electrical Loads for Off-Grid or Hybrid Operation

Desmond Young

Abstract— In building services electrical design, a key element of any project will be assessing the electrical load requirements. This needs to be done early in the design process to allow the selection of infrastructure that would be required to meet the electrical needs of the type of building. The type of building will define the type of assessment made, and the values applied in defining the maximum demand for the building, and ultimately the size of supply or infrastructure required, and the application that needs to be made to the distribution network operator, or alternatively to an independent network operator. The fact that this assessment needs to be undertaken early in the design process provides limits on the type of assessment that can be used, as different methods require different types of information, and sometimes this information is not available until the latter stages of a project. A common method applied in the earlier design stages of a project, typically during stages 1,2 & 3, is the use of benchmarks. It is a possibility that some of the benchmarks applied are excessive in relation to the current loads that exist in a modern installation. This lack of accuracy is based on information which does not correspond to the actual equipment loads that are used. This includes lighting and small power loads, where the use of more efficient equipment and lighting has reduced the maximum demand required. The electrical load can be used as part of the process to assess the heat generated from the equipment, with the heat gains from other sources, this feeds into the sizing of the infrastructure required to cool the building. Any overestimation of the loads would contribute to the increase in the design load for the heating and ventilation systems. Finally, with the new policies driving the industry to decarbonise buildings, a prime example being the recently introduced London Plan, loads are potentially going to increase. In addition, with the advent of the pandemic and changes to working practices, and the adoption of electric heating and vehicles, a better understanding of the loads that should be applied will aid in ensuring that infrastructure is not oversized, as a cost to the client, or undersized to the detriment of the building. In addition, more accurate benchmarks and methods will allow assessments to be made for the incorporation of energy storage and renewable technologies as these technologies become more common in buildings new or refurbished.

Keywords— energy, ADMD, electrical load assessment, energy benchmarks.

Modeling Sediment Transports under Extreme Storm Situation along Persian Gulf North Coast

Majid Samiee Zenoozian

Abstract— The Persian Gulf is a bordering sea with a normal depth of 35 m and a supreme depth of 100 m near its narrow appearance. Its lengthen bathymetric axis divorces two main geological shires — the steady Arabian Foreland and the unbalanced Iranian Fold Belt — which are imitated in the conflicting shore and bathymetric morphologies of Arabia and Iran. The sediments were experimented with from 72 offshore positions through an oceanographic cruise in the winter of 2018. Throughout the observation era, several storms and river discharge actions happened, as well as the major flood on record since 1982. Suspended-sediment focus at all three sites varied in reaction to both wave resuspension and advection of river-derived sediments. We used hydrological models to evaluation and associate the wave height and inundation distance required to carriage the rocks inland. Our results establish that no known or possible storm happening on the Makran coast is accomplished of detaching and transporting the boulders. The fluid mud consequently is conveyed seaward due to gravitational forcing. The measured sediment focus and velocity profiles on the shelf provide a strong indication to provision this assumption. The sediment model is joined with a 3D hydrodynamic module in the Environmental Fluid Dynamics Code (EFDC) model that offers data on estuarine rotation and salinity transport under normal temperature conditions. 3-D sediment transport from model simulations specify dynamic sediment resuspension and transport near zones of highly industrious oyster beds.

Keywords— sediment transport, storm, coast, fluid dynamics.

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Abstract —

In recent years, artificial intelligence (AI) has been on the rise as a transformative technology. AI apps address the loopholes that prevent students from achieving excellence in a conventional classroom setting. As a result, even slow learners can gain a better understanding of otherwise complex topics. Utilizing spare time for learning is a critical demand in mobile education today. Educational apps have the characteristic of portability, so they are highly suitable for this kind of demand and contribute to learning at your fingertips, becoming a new growth area of mobile education. For further research on educational apps, it is necessary to understand the current situation and prospects. In this paper, we discuss the opportunities and challenges posed by artificial intelligence educational apps based on a survey conducted with student experiences.

Keywords — Complex algebra, Mathematics, Matrix solutions, Complex graphs.

I. INTRODUCTION

Mathway gives pupils the skills they need to comprehend and solve arithmetic issues. Mathway is the most popular problem-solving resource for students, families, and instructors, with millions of customers and billions of questions done.

Mathway is a free calculator software that provides immediate answers to the user's most complicated arithmetic equations. From simple arithmetic problems, geometry, and algebra to more complicated calculus equations and trigonometry, the app effectively answers everything. Mathway is both an app and a website that works with browsers, iPhones, iPad, and Android devices.

The free edition merely provides the answers, but membership provides step-by-step solutions to a wide range of arithmetic problems. Mathway Calculator is a must-have program for any student who is having difficulty with math difficulties. A great topic glossary and an easy-to-use design make it simple to utilize.

Mathway has an almost mystical quality about it. A math problem can be typed in, but it can also be photographed. Once the photo has been trimmed to reflect only the problem in question, the program goes to work and displays the solution to the users. Another option is to speak the issue to the app, which will convert your words into an on-screen problem. If you prefer to fill in the issue, the program has a highly

complete keyboard that includes all of the arithmetic symbols you may require.

The software is quite successful in identifying the problem regardless of how it is configured. It is no less capable of addressing the problem, and it does so precisely and rapidly.

II. BACKGROUND

Mathway was founded in 2002 by childhood friends Frank Balcavage and Jake Kuehner with the aim to make access to learning easier for students and acknowledging that not everyone can afford tutors. In 2019, Chegg acquired Mathway for roughly \$100 million paid in cash up front.

Chegg Study is a membership service that provides homework assistance. Specifically, you can use Chegg's database to hunt up answers to questions contained in textbooks. You can also ask experts new questions, which they should be able to answer between 30 minutes to 24 hours.

Textbook Solutions and Expert Q&A are the two main services offered by Chegg Study.

You may find step-by-step homework answers by searching for your book by title or ISBN, then browsing by chapter and problem number with Textbook Solutions. For almost 9,000 books, there are over 21 million solutions available. Some books come with guided video walkthroughs and supplementary practice sets.

Moreover the downside of using the Chegg study app is how slow it is to find a response to the questions intended since there is no specific time for waiting it is an open limit of 30 min to 24 hours therefore it's impractical to help solve any kind of assignment or problem

Socratic is a Google learning tool that assists high school and university students in comprehending their schoolwork. It connects students to useful educational resources from the web and sites like YouTube using Google's artificial intelligence (AI) and searches capabilities.

Socratic uses artificial intelligence to expand its search capabilities, using technology such as text-to-speech and imagery analysis to assist learners to grasp everything from general information to obtaining in-depth expertise.

Socratic, unlike its main search engine, focuses on academic-related searches, making its resources more likely to be reliable and trustworthy. The app is free of extraneous junk at the time of authoring.

On the other hand, many users have mentioned that the Socratic google app is not as advanced in answering high school or even college level questions since it is mostly based around elementary and middle school. Even so Socratic only help I'm finding other websites that may help solve your inquiries but Socratic itself does not solve the question asked.

III. METHDOLOGY

Insert an equation of 2nd degree with a fraction after its sent a multiple choices showed up to choose between many solution for this equation it can automatically chosen to graph it then in less than one second the graph appeared with the equation desired with all steps required to draw this graph like finding slope the y-intercept, different points and all required steps (fig.1).

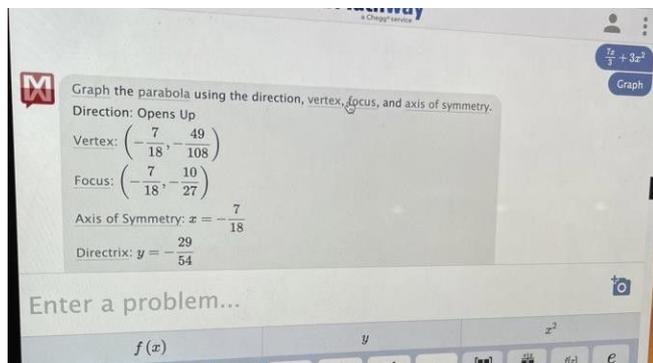


Figure 1. Equation of second-degree solution and graphing

Equation inserted the options shown again to choose in between. A search tab is also shown to search whatever option selected in math like for example finding the convex that is not shown in the first 10 options, but it appeared in the search button, then factoring was selected. The factorization form directly appeared with a show step option. the steps include all required procedure to do it like expand then reduce then factorize and it labels the factoring form as grouping by factorization which is one of 5 ways to factorize an equation (fig.2).

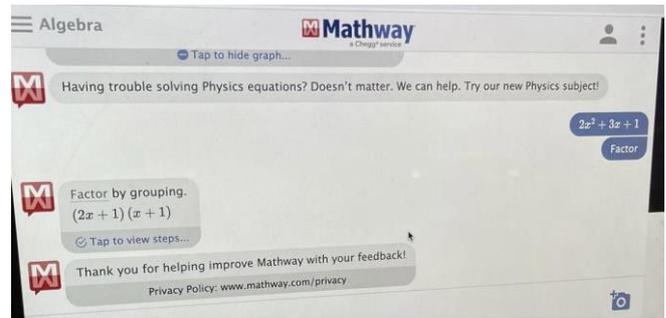


Figure 2. Factoring of a polynomial equation through Mathway

Function inserted the choosing criteria appeared again Then derivative is chosen and also it directly showed the solution derivative of this function then a message appeared below the solving that detects if there is any mathematical formula that include calculus problems (You are currently in the Algebra section, but it looks like you might be trying to do calculus. You might find more of the topics and symbols you need if you switch your subject over to Calculus.) the app showed the choice to switch to another program for calculus only (fig.3).

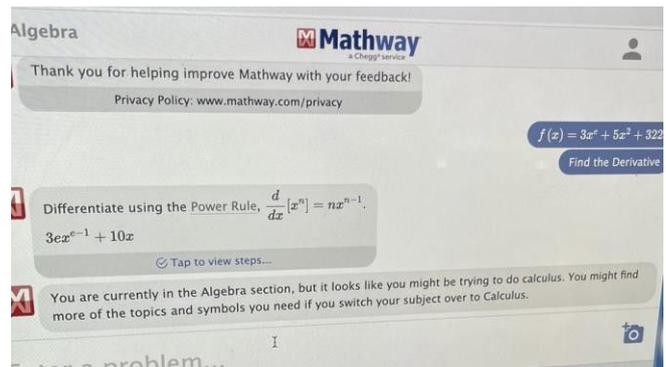


Figure 3. Derivative solution through Mathway

A polynomial function was chosen of 4th degree, then the same options appeared, finding the limit of this polynomial was selected, the app showed the derivative(fig.4), and the option to locate the limit desired by graphing the polynomial (fig.5).

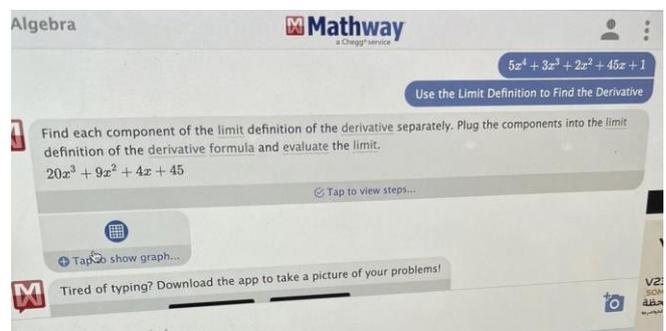


Figure 4. Finding derivative and limit of a polynomial

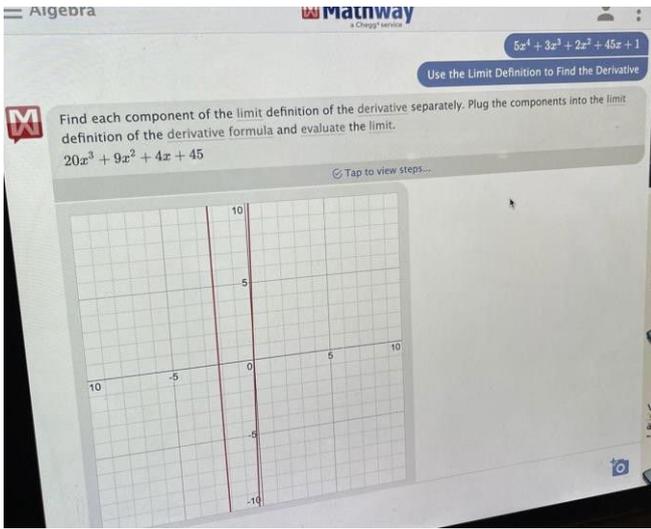


Figure 5. graphing the limit of derivative polynomial

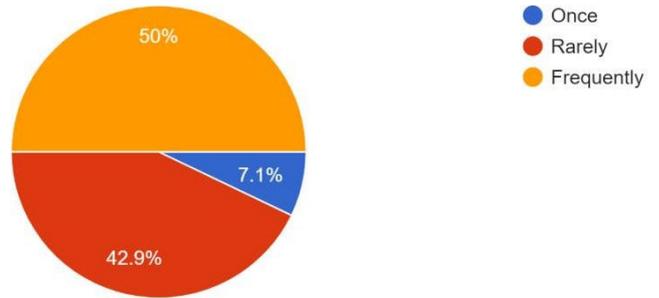


Figure 3. The number of times the application was used

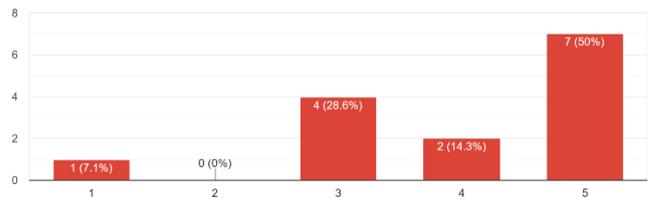


Figure 4. The accuracy of the answers provided

IV. RESULTS

After discussing the survey and spreading it, most of the responders mentioned that Mathway application highly met their expectations (Fig. 1).

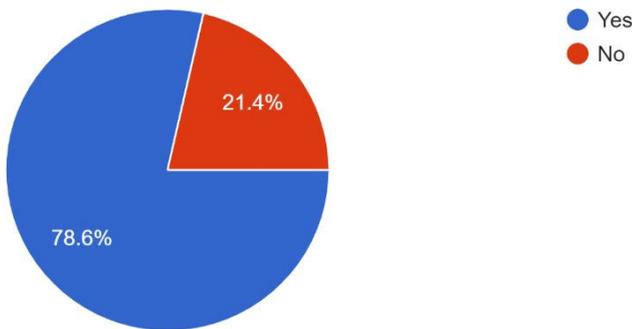


Figure 1. the expectations of the application users

We can understand that the application did not only gave the goal but also the exact goal that the user needed. In addition, the study show that the application is used frequently by the users as they could achieve their answers and at the same time the accuracy of the answers where perfect (Fig. 2-4).

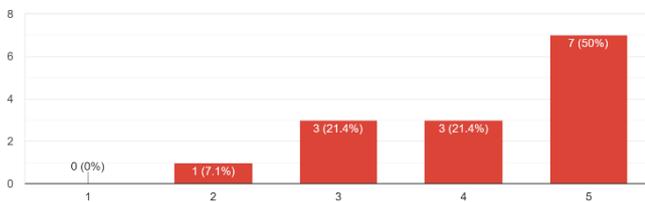


Figure 2. Shows the scale of goals achieved by the application

Moreover, other participation mentioned that the most features that they liked about the application is the ability of detecting the question through a camera or picture and the speed of showing the answers (Fig. 5).

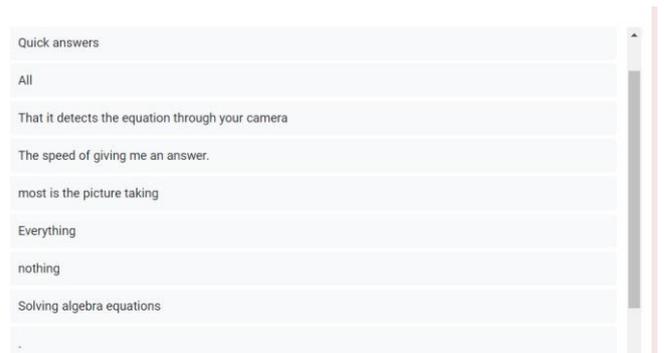


Figure 5. Features liked about the program

V. CONCLUSION

Mathway had proven to be an extremely efficient application. It's ability to streamline the users process of use left most participants satisfied for multiple reasons. The application's ability to detect questions through the camera lense, it's ability to give answers quickly and it's ability to provide correct answers as well as the working out. Our results have just emphasised why Mathway is one of the most used academic applications in the world. Our sample study relayed back to us the same feedback we found online about it's simplicity, efficiency, and reliability. It is clear that this application is one of a kind and will only improve here on out.

REFERENCES

[1] BATERNA, Q. (2021). *What Is Google Socratic and How Does It Work?*. MUO. Retrieved 26 March 2022, from

<https://www.google.com/amp/s/www.makeuseof.com/what-is-google-socratic-how-does-it-work/amp/>.

[2] Firmage, M. (2020). Horizon Advises Mathway on Acquisition by Chegg - Horizon Partners. Horizon Partners. Retrieved 26 March 2022, from <https://horizonpartners.com/horizon-advises-mathway-acquisition-chegg/#:~:text=Mathway%2C%20founded%20in%202002%20by,fully%2Dautomated%20online%20math%20tutor.>

[3] Mathway | About Us. Mathway.com. (2022). Retrieved 26 March 2022, from <https://www.mathway.com/about#:~:text=About%20Mathway,students%2C%20parents%2C%20and%20teachers.>

[4] Mathway for iOS or Android - Free Download - Educational App Store. Educational App Store. Retrieved 26 March 2022, from <https://www.educationalappstore.com/app/mathway.>

[5] Socratic by Google Reviews 2022 | JustUseApp Reviews. JustUseApp. (2020). Retrieved 26 March 2022, from <https://justuseapp.com/en/app/1014164514/socratic-by-google/reviews#reviews.>

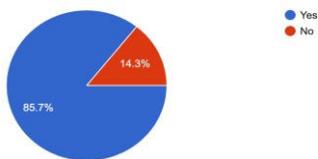
[6] WIRE, B. (2020). Chegg Acquires Mathway to Expand Its Math Offerings Globally. Businesswire.com. Retrieved 26 March 2022, from <https://www.businesswire.com/news/home/20200604005631/en/Chegg-Acquires-Mathway-to-Expand-Its-Math-Offerings-Globally.>

APPENDIX

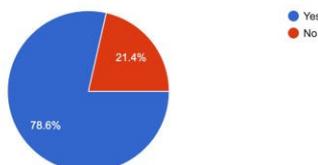
The Survey Questions and the figures:

1. Have you used Mathway application before?
2. Was it easy to use?
3. How many times have you used it?
4. Did the application help meet your expectation?
5. How do you rate its accuracy?
6. Did Mathway application help you solve your problem/achieve your goal?
7. How would you rate the overall quality of the app?

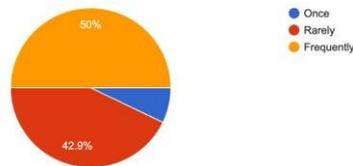
Have you used Mathway application before?
14 responses



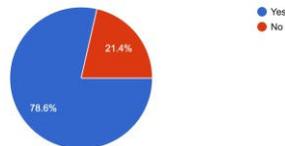
Was it easy to use?
14 responses



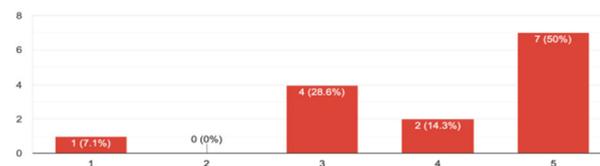
how many times have you used it?
14 responses



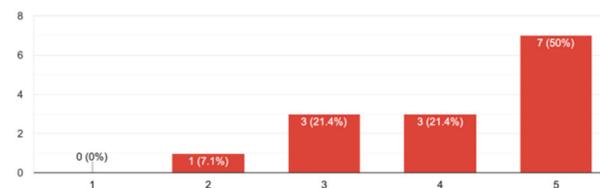
Did the application help meet you expectation?
14 responses



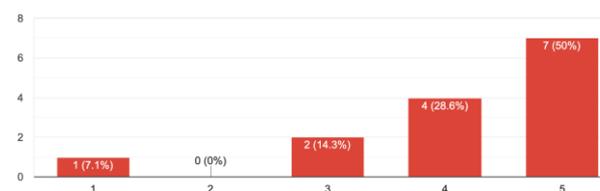
How do you rate its accuracy?
14 responses



Did Mathway application help you solve your problem/achieve your goal?
14 responses



How would you rate the overall quality of the app?
14 responses



Fabrication of Textile-Based Radio Frequency Metasurfaces

Adria Kajenski, Guinevere Strack, Edward Kingsley, Shahriar Khushrushahi, Alkim Akyurtlu

Abstract— Radio Frequency (RF) metasurfaces are arrangements of subwavelength elements interacting with electromagnetic radiation. These arrangements affect polarization state, amplitude, and phase of impinging radio waves; for example, metasurface designs are used to produce functional passband and stopband filters. Recent advances in additive manufacturing techniques have enabled the low-cost, rapid fabrication of ultra-thin metasurface elements on flexible substrates such as plastic films, paper, and textiles. Furthermore, scalable manufacturing processes promote the integration of fabric-based RF metasurfaces into the market of sensors and devices within the Internet of Things (IoT). The design and fabrication of metasurfaces on textiles require a multidisciplinary team with expertise in i) textile and materials science, ii) metasurface design and simulation, and iii) metasurface fabrication and testing. In this presentation, we will discuss RF metasurfaces on fabric with an emphasis on how the materials, including fabric and inks, along with fabrication techniques, affect the RF performance. We printed metasurfaces using a direct-write approach onto various woven and non-woven fabrics, as well as on fabrics coated with either thermoplastic or thermoset coatings. Our team also performed a range of tests on the printed structures, including different inks and their curing parameters, wash durability, abrasion resistance, and RF performance over time.

Keywords— electronic textiles, metasurface, printed electronics, flexible.

A Literature Study on IoT Based Monitoring System for Smart Agriculture

Sonu Rana, Jyoti Verma, A. K. Gautam

Abstract— In most developing countries like India, the majority of the population heavily relies on agriculture for their livelihood. The yield of agriculture is heavily dependent on uncertain weather conditions like a monsoon, soil fertility, availability of irrigation facilities and fertilizers as well as support from the government. The agricultural yield is quite less compared to the effort put in due to inefficient agricultural facilities and obsolete farming practices on the one hand and lack of knowledge on the other hand, and ultimately agricultural community does not prosper. It is therefore essential for the farmers to improve their harvest yield by the acquisition of related data such as soil condition, temperature, humidity, availability of irrigation facilities, availability of, manure, etc., and adopt smart farming techniques using modern agricultural equipment. Nowadays, using IOT technology in agriculture is the best solution to improve the yield with fewer efforts and economic costs. The primary focus of this work-related is IoT technology in the agriculture field. By using IoT all the parameters would be monitored by mounting sensors in an agriculture field held at different places, will collect real-time data, and could be transmitted by a transmitting device like an antenna. To improve the system, IoT will interact with other useful systems like Wireless Sensor Networks. IoT is exploring every aspect, so the radio frequency spectrum is getting crowded due to the increasing demand for wireless applications. Therefore, Federal Communications Commission is reallocating the spectrum for various wireless applications. An antenna is also an integral part of the newly designed IoT devices. The main aim is to propose a new antenna structure used for IoT agricultural applications and compatible with this new unlicensed frequency band. The main focus of this paper is to present work related to these technologies in the agriculture field. This also presented their challenges & benefits. It can help in understanding the job of data by using IoT and correspondence advancements in the horticulture division. This will help to motivate and educate the unskilled farmers to comprehend the best bits of knowledge given by the huge information investigation utilizing smart technology.

Keywords— smart agriculture, IoT, agriculture technology, data analytics, smart technology.

Experimental Study of CO₂ Hydrate Formation in Presence of Different Promotors

Samaneh Soroush, Tommy Golczynski, Tony Spratt

Abstract— One of the new technologies for CO₂ capture, storage, and utilization (CCSU) is forming clathrate hydrate. This technology has some unknowns and challenges that make it difficult to apply in real world. The low formation rate is one of the main difficulties of CO₂ hydrate. In this work the effect of different promotors on the hydrate formation rate has been studied. Two surfactant Sodium Dodecyl Sulfate (SDS), Tetra-n-butylammonium bromide (TBAB) and cyclopentane (CP) as a thermodynamic promotor and their combination have been used for the experiments. The results showed that the SDS is a powerful kinetic promotor and its combination with CP helps to convert more CO₂ to hydrate in a short time.

Keywords—Carbon capture, carbon dioxide, hydrate, promotor.

Farmers' Perception and Response to Climate Change Across Agro-ecological zones in Conflict-Ridden Communities in Cameroon

L.N. Fonjong

Abstract— The livelihood of rural communities in the West African state of Cameroon which is largely dictated by natural forces (rainfall, temperatures, and soil) is today threatened by climate change and armed conflict. This paper investigates the extent to which rural communities are aware of climate change, how their perceptions of changes across different agro-ecological zones have impacted farming practices, output, and lifestyles, on the one hand, and the extent to which local armed conflicts are confounding their efforts and adaptation abilities. The paper is based on a survey conducted among small farmers in selected localities within the forest and savanna ecological zones of the conflict-ridden Northwest and Southwest Cameroon. Attention is paid to farmers' gender, scale, and type of farming. Farmers' perception of and response to climate change are analysed alongside local rainfall and temperature data, and mobilization for climate justice. Findings highlight the fact that farmers' perception generally corroborates local climatic data. Climatic instability has negatively affected farmers' output, food prices, standards of living, and food security. However, the vulnerability of the population varies across ecological zones, gender, and crop types. While these factors also account for differences in local response and adaptation to climate change, ongoing armed conflicts in these regions have further complicated opportunities for climate-driven agricultural innovations, inputs, and exchange of information among farmers. This situation underlines how poor communities, as victims, are forced into many complex problems outside their making. It is therefore important to mainstream farmers' perceptions, and differences, into policy strategies that consider both climate change and Anglophone conflict as national security concerns for sustainable development in Cameroon.

Keywords—adaptation policies, climate change, conflict, small farmers, Cameroon.

Evaluating Climate Risk and Enhancing Resilience in Durban, South Africa

Cabangile N. Ngwane, Gerald Mills

Abstract— Anthropogenic climate change is exacerbating natural hazards such as droughts, heatwaves and sea-level rise. The associated risks are the greatest in places where socio-ecological systems are exposed to these changes and the populations and infrastructure are vulnerable. Identifying the communities at risk and enhancing local resilience are key issues in responding to the current and project climate changes. The paper explores the types of risks associated with multiple overlapping hazards in Durban, South Africa where the social, cultural and economic dimensions that contribute to exposure and vulnerability are compounded by its history of apartheid and colonisation. As a result, climate change risks are highly concentrated in marginalized communities that have the least adaptive capacity. In this research, a Geographic Information System is to explore the spatial correspondence among geographic layers representing hazards, exposure and vulnerability from Open Data Durban (<https://africaopendata.org/>). This quantitative analysis will allow authors to identify communities with high exposure and focus the study on the nature of the current human-environment relationships that results in vulnerability. This analysis will direct the qualitative approach to critically examine policies (including educational practices and financial support systems) and on-the-ground actions that are designed to improve the adaptive capacity of these communities and meet UN Sustainable Development Goals. This means that a mixed methods approach will be utilized. The work will contribute to a growing body of literature on disaster risk management, especially as it relates to developing economies where socio-economic inequalities are correlated with ethnicity and race.

Keywords—: adaptive capacity, disaster risk reduction, exposure, resilience, South Africa.

Climate Related Financial Risk for Automobile Industry & Impact to Financial Institutions

Mahalakshmi. S

INTRODUCTION

Abstract

As per the recent changes happening in the global policies, climate related changes and the impact it causes across every sector are viewed as green swan events – in essence, climate related changes can happen often and lead to risk and lot of uncertainty, but needs to be mitigated instead of considering them as black swan events. This brings about a question on how this risk can be computed, so that the financial institutions can plan to mitigate it.

Climate related changes impact all risk types – credit risk, market risk, operational risk, liquidity risk, reputational risk and other risk types. And the models required to compute this has to consider the different industrial needs of the counterparty, as well as the factors that are contributing to this – be it in the form of different risk drivers, or the different transmission channels or the different approaches and the granular form of data availability.

This brings out to the suggestion that the climate related changes, though it affects Pillar I risks, will be a Pillar II risk. This has to be modeled specifically based on the financial institution's actual exposure to different industries, instead of generalizing the risk charge. And this will have to be considered as the additional capital to be met by the financial institution in addition to their Pillar I risks, as well as the existing Pillar II risks.

In this paper, the author presents a risk assessment framework to model and assess climate change risks - for both credit and market risks. This framework helps in assessing the different scenarios, and how the different transition risks affect the risk associated with the different parties. This research paper delves on the topic of increase in concentration of greenhouse gases, that in turn causing global warming. It then considers the various scenarios of having the different risk drivers impacting Credit and market risk of an institution, by understanding the transmission channels, and also considering the transition risk.

The paper then focuses on the industry that's fast seeing a disruption: automobile industry. The paper uses the framework to show how the climate changes and the change to the relevant policies have impacted the entire financial institution. Appropriate statistical models for forecasting, anomaly detection and scenario modeling are built to demonstrate how the framework can be used by the relevant agencies to understand their financial risks.

The paper also focuses on the climate risk calculation for the Pillar II Capital calculations, and how it will make sense for the bank to maintain this in addition to their regular Pillar I and Pillar II capital.

Keywords— capital calculation, climate risk, credit risk, pillar ii risk, scenario modeling.

Climate Related changes have been happening in the environment since time immemorial, but during the recent past, the number of occurrences have increased. We can see that there are multiple occasions when the global warming has affected and caused the increase in the temperature, which is again caused due to multiple reasons like deforestation, carbon emissions etc. The increase in the temperature has caused an impact across the globe – be it in the case of the Great Barrier Reef in Australia, where the sea and air temperatures are increasing, and the entire shallow water coral reefs have been eroded by almost 50% in the recent years, or the melting of the ice and snow in the Arctic region. There have also been other climate related changes like more occurrence of tsunamis and earthquakes and other natural disasters.

This led to the signing of the international treaty of Paris Agreement 2016, that mandatorily made all countries to pledge for reducing the average global warming temperature by atleast 2 degree Celsius, compared to pre-industrial levels. To achieve this goal, all the countries aim to reduce the greenhouse gas emissions as soon as possible.

All these climate related changes and its effects are seen as one off events by the different financial institutions. The different financial institutions in focus are the banks, insurance firms, securities firms and other financial institutions. They consider any of these climatic changes and the impact it brings to the financial institutions as black swan events, and don't consider any of it in their risk management practices. For example, any housing loan issued to a person and the property being caused damage due to tsunami is not completely considered for computing the risk of the bank. Though slowly there are insurance coverage and other kind of mitigants to handle these risks, this is still not wide-spread.

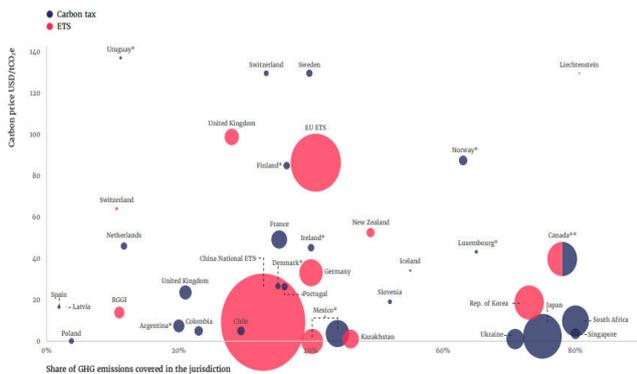
This brings out a need for the framework to handle the financial risks caused by these climate changes, and the financial institutions have to consider these as green swan events, and not as black swan events. In essence, this means, that the financial institutions have to be prepared for the climate related change and the associated risks, and have to mitigate it, and wherever not possible, hold additional capital to take care of the loss. As mentioned, nowadays, banks are considering mortgages to be associated mandatorily with insurance, as they are slowly moving towards mitigation of climate related risks.

WHY AUTOMOBILE INDUSTRY?

Automobile Industry is one of the most impacted one, due to the climate related policy initiatives. And this industry is the backbone for all, and impacts every one – the layman to the business man, to the economy in either direct or indirect manner. There are lot of financial assistance provided by government to help the automobile firms in coming up with latest technological changes that would reduce the carbon emissions. The paper (Baycan & TO, 2021) have detailed on how the carbon emission of each vehicle is computed, and it has been proved that the emissions of vehicles running on Gasoline or Petrol, LPG and Diesel are all high and the major breakthrough was on the usage of the electric vehicles, wherein electricity has to be generated using renewal energy. This is the same strategy now being followed by all the countries, wherein they are moving away from the fossil fuels to something based on renewable energy. This can either be in the form of electric vehicles or hydrogen vehicles or other forms of vehicles.

The Figure 1 details the greenhouse gas emissions by different countries, and the share of them covered by the Carbon tax and its related instruments. Many countries have started levying carbon tax, and expect that all industries will mandatorily pay the appropriate carbon tax, that is determined on the basis of their greenhouse gas emissions.

Figure1: Absolute emissions coverage, share of emissions covered, and prices for CPIs (The World Bank, 2022)



EFFECT OF CLIMATE RISK ON BANKS

The climate risk, as we can see above, will have different effect for each party type. The different financial institutions have an effect according to their nature of business. For example, a bank in the lending business will be more impacted by the lending it does to the auto industry, and it needs to come up with a strategy to price the products differently for a green business versus a business that is dependent on fossil fuel. The paper by (Delis, Greiff, & Ongena, 2019) talk about this in detail, and provide the basis for pricing the syndicate loans. The

same strategy can also be used by the banks to price the products.

This paper attempts at identifying the effect of climate risk on banks. The paper by (Delis, Greiff, & Ongena, 2019) also has provided the different fossil fuel reserves used as variables for modeling the impact on the automobile industry.

Table 1 gives the details of the same

Table1: Fossil Fuel Firm’s Reserves Data (Delis, Greiff, & Ongena, 2019)

Variable	Description	Source
Fossil Fuel Reserves	Fossil fuel firms’ relative amount of oil, gas and coal reserves by countries.	Annual reports and own calculations
Proved Reserves (USD)	Standardized measure of discounted future net cash flows related to proved oil and gas reserves (in million USD).	idem
Climate Policy Exposure	The climate policy exposure of fossil fuel firms determined by weighting the countries’ climate policy index by the relative amount of a firm’s fossil fuel reserves of each firm in each year in that country (see equation 1). As climate policy indices we use the C3I and CCPI.	Annual reports and climate policy indices
Climate Policy Exposure by Headquarter	The climate policy exposure of the fossil fuel firms’ headquarter determined by climate policy index of the country of the firms’ headquarter. As climate policy indices we use the C3I and CCPI.	idem
Political Instability Exposure	The political instability exposure of fossil fuel firms determined by weighting the countries’ political instability index by the relative amount of a firm’s fossil fuel reserves of each firm in each year in that country	Annual reports and political instability indices

FRAMEWORK FOR CALCULATING THE RISK

The climate risk assessment has a high level framework that involves risk identification, and ensuring that the different types of risk are categorized. The risks need to be categorized into physical risk, wherein the risk gets assigned based on the economic costs and the financial losses that result from the physical changes in the environment, and as well as transition risk, wherein they are related to business and have an indirect impact. In the case of Automobile industry, the microeconomic and macroeconomic factors also play an important role, and

they get classified and treated as transmission channels, as this is the driving change.

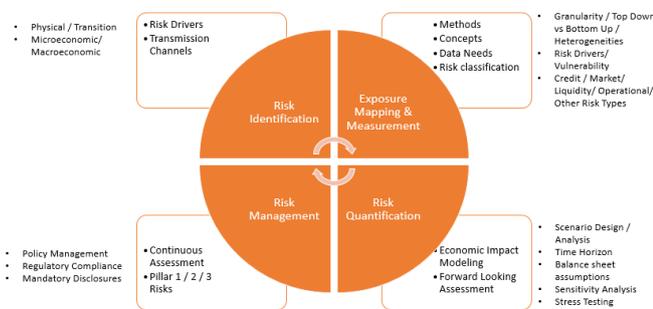
The exposures of the bank need to be then mapped and measured based on the kind of data that are available. This can be assessed in the form of more granular data (which is the bottom up approach) or doing the computations based on high level data (which is the top down approach), and also multiple scenarios of data can be considered. The analysis of the data has to be done to ensure that they are classified into different risk types – credit risk, market risk, liquidity risk etc. In this framework, the suggestion is to use based on the kind of data that is available, and accordingly model it out.

The risk quantification happens based on the modeling of economic impact, which is by the usage of scenario analysis and sensitivity analysis. The scenario analysis is the preferred mechanism for the calculation of the climate related financial risks, as there can be different factors affecting the different automobile customers, on the basis of their microeconomic factors, and internal policies and data availability.

The risk management, is based on the continuous assessment and calculation according to the different risk types. There are mandatory disclosures required for the same. This also gets handled as part of internal risk management policies to ensure that the risks are being managed efficiently and also by following any mandatory regulatory compliance provided by the regulators.

Figure 2 gives a snapshot view of this framework.

Figure2 Climate Risk Assessment Framework



WHY SCENARIO ANALYSIS AND CAUSAL MODELING?

The Scenario Analysis and Causal modeling mechanism has been considered as part of this paper to compute the Climate related financial risk. This mechanism helps in identifying the causes behind the processes that take place in the system. This demonstrates the importance of random allocation of units and the industry knowledge can help in improving the weights that are being given to the different factors. And this mechanism also provides the benefits of replication of the model, if there is a need for it.

The causal inference is a combination of logical and statistical methods. And this helps in identifying the relationship between cause and effect. This also helps in identifying how any cause can change different effects and hence the capital can be different for the same. And the

regression models are not preferred, as this can have any combination of dependent and independent variables.

MODEL PROPOSED

The climate related financial risk has to be split and derived for each risk type differently. This cannot be clubbed together with all the other risk types, as each risk will have its own risk drivers, and risk drivers also play a vital role in the calculation. And for each risk driver (which can be any physical risk driver or a transition risk driver), the impact a micro economic factor or a macro economic factor has are different. And also, this changes on the basis of how the particular financial institution has maintained the data. If we are looking at the data availability, the factor that is being assigned to individual exposures’ data (Bottom up approach of data availability) will be different from the factor that gets assigned to the total exposures’ data (top down approach of data availability), as the other relevant attributes required for the capital charge will not be available in the case of the top down approach of data.

The factors or in statistical terms, the weights that are assigned to each of the input used for the calculation will be different, and this cannot be generalized as this will be specific to the various attributes like data availability, and the micro economic factors and the risk driver can change for each automobile industry participant.

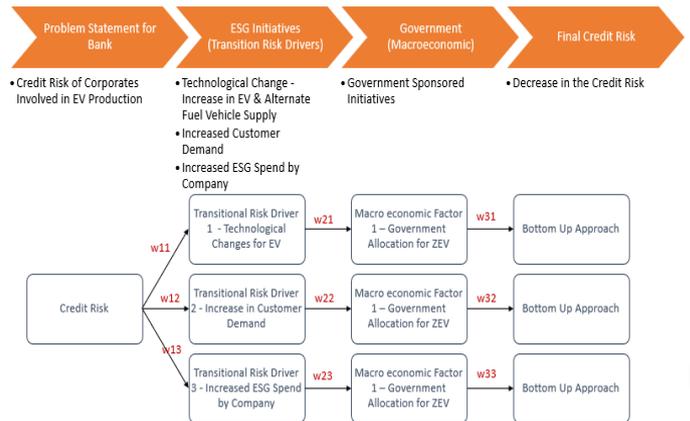
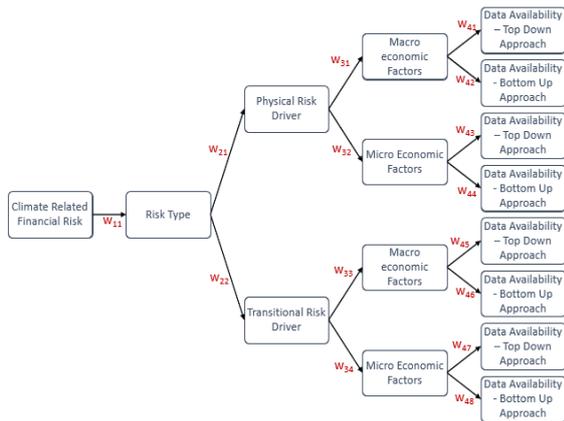
The model formulae for calculating the capital charge related to any risk is as below:

$$\begin{aligned}
 & \text{Capital Charge for Each Risk Type} \\
 & = \sum(\text{Individual Risk Drivers} \\
 & * \text{the Weight Assigned for the Individual Risk Driver}) \\
 & * \left(\text{Different Transmission Channels} * \text{the weight assigned for} \right. \\
 & \quad \left. \text{the different transmission channels} \right) \\
 & * \text{(Data Granularity)} \\
 & * \text{the weight assigned for the data granularity)}
 \end{aligned}$$

And this capital charge gets aggregated across risk types to arrive at the total risk charge to be maintained by the financial institution. On the basis of the above, and the figure 3, which details the logic of the scenario analysis model, the below will be the climate related financial risk for a single risk type, having a single risk driver and a single macro economic factor, but with different data granularity.

$$\begin{aligned}
 & \text{Climate Related Financial Risk for a Single Risk Type} \\
 & = ((\text{Physical Risk Driver 1} * w21) \\
 & * (\text{Macro economic Factor 1} * w31) * \\
 & * (\text{Top Down Approach Data} * w41)) \\
 & + ((\text{Physical Risk Driver 1} * w21) \\
 & * (\text{Macro economic Factor 1} * w31) * \\
 & * (\text{Bottom up Approach Data} * w42))
 \end{aligned}$$

Figure3 Model for Climate Related Financial Risk



APPLYING THE MODEL TO AUTOMOBILE INDUSTRY

The above model can be assigned to the automobile industry on the basis of the mapping of the appropriate risk drivers, economic factors and the data granularity. Figure 4 provides this mapping of the model to a specific scenario of the automobile industry. The credit risk associated with the companies that are involved in the electric vehicle production have to be assessed differently from the regular corporates involved in the fossil fuel related vehicles production. There are multiple transitional risk drivers in this scenario like the technological changes that are being followed by the particular customer. It has been seen that corporates that have embraced the climate related changes have a higher brand value, as compared to corporates that are yet to embrace any of the technological changes.

There are also macro economic factors that affect the credit risk, like the government initiatives wherein the regulators and the central government are actually funding the cost, and also cover up as a guarantor for some of the corporates. And depending on the data, the calculation logic as mentioned changes.

The below will be the formulae for the calculation of the credit risk, as per the example in Figure 4, for one of the risk driver is as below.

$$\begin{aligned}
 & \text{Credit Risk} \\
 & = \left(\text{Changes caused due to Technological} \right. \\
 & \quad \left. \text{enhancements} * w11 \right) \\
 & * \left(\text{Changes caused due to Government Allocation} \right. \\
 & \quad \left. \text{for Zero Emission Vehicles} * w21 \right) \\
 & * \left(\text{Total Exposure Amount as per Bottom up Approach} \right. \\
 & \quad \left. * w31 \right)
 \end{aligned}$$

Figure4 Example of assigning the proposed model to a Corporate involved in Electric Vehicle Production

WHY PILLAR 2 CAPITAL

As can be seen in the above model and the example, the factors that are contributing to the total capital charge are determined by few corporate specific calculations like the microeconomic factors, data availability etc. This cannot be completely handled by making this a Pillar 1 calculation wherein the capital charge is computed based on the ratings of the counterparty and other solvency related parameters. But, this includes even reputational parameters like brand value, which helps in determining how the customers will buy the vehicles, and hence the capital charge to be maintained by the bank for each corporate can be different. And the Pillar 1 calculation already consider the credit enhancement which also considers a portion of the environment risk into it. So, all this points to the need of this climate related financial risk being a specific Pillar II Risk and not a Pillar I risk. This has to be maintained by the bank or the financial institution in addition to their existing Pillar I and Pillar II risk requirements.

CONCLUSION

On the basis of the above, it can be concluded that the climate related financial risk is a Pillar II risk, and can be computed the capital charge using the scenario modeling specified. There are additional scope of improvement in the model, by using deep learning to improvise the framework, and also by having additional industries analyzed using the same model, and adding the risk drivers that are going to be specific for each of them.

REFERENCES

- [1] Baycan, N., & TO, Z. (2021). Determination of Carbon Footprint of Automobile Origin in Izmir City. 3rd International Conference on the Sustainable Energy and Environmental Development (p. 10). Poland: IOP Conference Series: Earth and Environmental Science.
- [2] Bolton, P., & Kacperczyk, M. T. (2020). Do Investors Care about Carbon Risk? Columbia Business School Research Paper Forthcoming, 91.
- [3] Bowen, A., Cochrane, S., & Fankhauser, S. (2011). Climate change, adaptation and economic growth. Climatic Change, 113.
- [4] Cevik, S., & Jalles, J. T. (2020). This Changes Everything: Climate Shocks and Sovereign. IMF Working Papers, 24.
- [5] Delis, M. D., Greiff, K. d., & Ongena, S. (2019). Being Stranded with Fossil Fuel Reserves? Climate Policy Risk and the Pricing of Bank loans. EBRD Working Paper No. 231, 75.

- [6] The World Bank. (2022). State and Trends of Carbon Pricing 2022. Washington: International Bank for Reconstruction and Development / The World Bank.

Enhancement of CO₂ Capturing Performance of N-Methyldiethanolamine (MDEA) Using with New Class Functionalized Ionic Liquids: Kinetics and Interaction Mechanism Analysis

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Abstract— CO₂ capture using benign cost-effective solvents is an essential unit operation not only in the process industry for CO₂ separation and recovery from industrial off-gas streams but also for direct capture from air to clean the environment. Several solvents are identified, by researchers, with high CO₂ capture efficiency due to their favorable chemical and physical properties, interaction mechanism with CO₂, and low regeneration energy cost. However, N-Methyldiethanolamine (MDEA) is the most frequently used solvent for CO₂ capture with promoters such as piperazine (Pz) and monoethanolamine (MEA). These promoters have several issues such as low thermal stability, heat-stable salt formation, and being highly degradable. Therefore, new class promoters need to be used to overcome these issues. Functionalized ionic liquids (FILs) have the potential to overcome these limitations. Hence, in this work, four different new class functionalized ionic liquids (FILs) were used as promoters and determined their effectivity toward enhancement of the CO₂ absorption performance. The CO₂ absorption is performed at different pressure (2 bar, 4.4 bar, and 7 bar) and different temperature (303, 313, and 323K). The results confirmed that CO₂ loading increases around 18 to 22% after 5wt% FILs blended in the MDEA. It was noticed that the CO₂ loading increases with increasing pressure and decreases with increasing temperature for all absorbents systems. Further, the absorption kinetics was determined, and results showed that all the FILs provide an excellent absorption rate enhancement. Additionally, for the interaction mechanism study, ¹³C NMR analysis was performed for the blend aqueous MDEA-CO₂ system. The results suggested that the FILs blend MDEA system produced a high amount of carbamates and bicarbonates during CO₂ absorption, which further decreases with increasing temperature. Eventually, regeneration energy was calculated, and results confirmed that the energy heat duty penalty was lower in the [TETAH][Im] blend MDEA system. Overall, [TETAH][Pz], [TETAH][Im], [DETAH][Im] and [DETAH][Tz] showed the promising ability as promoters to enhance CO₂ capturing performance of MDEA.

Keywords— CO₂ capture, interaction mechanism, kinetics, Ionic liquids.

Factors Affecting the Mental and Physical Health of Nurses during the Outbreak of COVID-19: A Case Study of a Hospital in Mashhad

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Abstract

Background: Due to the widespread outbreak of the COVID-19 virus, a large number of people become infected with the disease every day and go to hospitals. The acute condition of this disease has caused the death of many people. Since all the stages of treatment for these people happen in the hospitals, nurses are at the forefront of the fight against this virus. This causes nurses to suffer from physical and mental health problems. **Methods:** Physical and mental problems in nurses were assessed using the Depression, Anxiety and Stress Scale (DASS-42) of Lovibond (1995) and the Nordic Questionnaire. **Results:** 90 nurses from emergency, intensive care, and coronary care units were examined, and a total of 180 questionnaires were collected and evaluated. It was found that 37.78%, 47.78%, and 21.11% of nurses have symptoms of depression, anxiety, and stress, respectively. 40% of the nurses had physical problems. In total, 65.17% of them were involved in one or more mental or physical illnesses. **Conclusions:** Of the three units surveyed, the nurses in intensive care, emergency room, and coronary care units worked more than ten hours a day. Examining the interaction of physical and mental health problems indicated that physical problems can aggravate mental problems.

Keywords

Depression Anxiety and Stress Scale of Lovibond (DASS-42), Nordic Questionnaire, Mental Health of Nurses, Physical Health Problems in Nurses

Introduction

The outbreak of COVID-19 virus in China and its gradual spread to most parts of the world has infected a lot of people with the disease, many of whom have died due to its unknown nature. Nurses and medical staff are always at risk of infection with this disease, which puts them at high-risk group.¹ They, as people at the forefront of the fight against the virus, also see patients die every day.² By examining the literature on infectious diseases such as COVID-19, it can be found that nurses are at greater risk of mental problems than other members of the medical staff.³ By December 20, 2020, according to the head of the country's nursing organization, about 145,000 nurses are taking care of patients from which about 60,000 nurses (41.3%) have been infected with this disease and about 100 nurses have died. There are currently 6,000 nurses in quarantine or on sick leave.⁴ Working in this environment has made them vulnerable to health

events and makes it difficult for nurses to provide services to patients and maintain their efficiency.⁵ The influx of large numbers of suspected infected people to the hospitals and the lack of resources have caused health care providers to worry.⁶ Based on a qualitative study in Iran during the outbreak of this virus, it was shown that nurses have suffered a lot of mental distress due to the death of patients, unknown dimensions of the disease and the atmosphere of the workplace. Not considering these issues will lead to a decrease in the number of nurses and damage to the health system in the face of crisis.³

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The negative impact of this virus on nurses has caused them to suffer from stress, anxiety, symptoms of depression, insomnia, anger and fear.^{2,7,8,9} When faced with a critical situation, stress and anxiety are common effects that occur in people. Nurses suffer from fatigue, burnout, mental turmoil, and emotional isolation due to working in such environment and conditions.¹⁰ They also play an important role in controlling infectious and contagious diseases, which is the reason that maintaining their health is so important.¹¹

Unpredictability of virus behavior in infected people, uncertainty about disease conditions and various aspects of epidemiology cause people to be stressed.¹² In addition to the high stress introduced during the outbreak of COVID-19,¹³ lack of access to adequate equipment, and dealing with the people infected and suspected of having this disease have also led to depression of nurses.¹⁴ Stress caused by COVID-19 is a major factor that can lead to depression and anxiety in nurses. Also, stressful hospital environment has caused nurses to be dissatisfied with their work and their tendency to leave work has become stronger.¹⁵

By comparing the condition of the nurses during and before the outbreak of COVID-19 epidemic, it is concluded that changes have been made in their physical condition.¹⁶ Previous studies have shown that this disease has also affected the physical and mental health of medical staff.¹⁷ Due to the long working hours and heavy workload, it is predictable that nurses' health will be endangered.¹⁸

In this study, the physical and mental health of nurses is investigated. All nurses of a hospital in Mashhad, Iran, dealing with coronavirus were studied in terms of mental health including stress, anxiety and depression and in terms of physical health including musculoskeletal pain. Because women are more threatened by physical injuries than men,¹⁹ they made up 45.16% of our population. Also, this study was performed on 46.67% of nurses exposed to more work pressure in the emergency department.^{20,21}

The objective of this study was to investigate the factors affecting the mental and physical health of nurses. Age, type of activity, gender, working hours and sports activity are the factors that affect the severity of mental and physical symptoms caused

by COVID-19. In addition, the interaction of physical health on mental health is also examined.

Materials and methods

The present study is a cross-sectional study conducted in one of the hospitals accepting patients with COVID-19 in Mashhad. The place that was studied is one of the hospitals in Mashhad that has a major role in fighting this disease. The metropolis of Mashhad is the second most populous city in Iran, which is located in northeastern Iran. This metropolis has also had a significant number of cases during the outbreak of COVID-19. Emergency department, intensive care unit (ICU) and coronary care unit (CCU) were considered to determine the population of nurses. The emergency department was selected based on previous studies²² and the other two units by us and based on the observation of nurses' work pressure.

This scale was introduced in 1995 by Lovibond²³ and is available in two 21-question short version and 42-question long version. The 21-question version is the abbreviated form of 42-question version. In this study, the 42-question stress, anxiety and depression questionnaire of Lovibond was used, the answer options of which are based on the four-point Likert scale. Each of the factors of stress, anxiety and depression is examined with 14 different questions. The validity of this questionnaire in Iran was confirmed by Afzali Moghadam et al. in 2007 which performed a psychometric study on 400 high school students in Kermanshah. Cronbach's alpha coefficient calculated for depression, anxiety and stress were respectively 0.94, 0.85 and 0.87 which was highly correlated with Cronbach's alpha of Lovibond.²⁴

The Nordic Questionnaire is used to assess musculoskeletal injuries.²⁵ This type of questionnaire examines pain in nine parts of the body. These 9 parts include the neck, shoulders, upper back, elbows, waist, wrists, thighs and hips, knees and ankles. Shoulders, elbows and wrists are questioned as pain in the left and right parts, but question about pain in other parts is as yes/no. If the respondent answers yes to one of the parts, he / she will move on to the next questions.

The data obtained from the questionnaires in this study was entered into SPSS software (version 23). Non-parametric tests were used due to the number of 90 nurses and abnormal data behavior. Non-parametric Kruskal-Wallis and Mann-Whitney U tests were used to examine factors affecting depression, anxiety and stress due to the qualitative nature of some variables, and Spearman non-parametric test was used to examine the relationship between Nordic questionnaire and Lovibond's depression, anxiety and stress scale (DASS-42) (1995). P-value =

0.05 was determined to evaluate the level of significance and interpretation of the tests. The percentages mentioned below are the percentages of the total number of nurses surveyed. Although the missing data in our study was very small, the slight difference between the percentages in some sections is due to the missing data.

Results

In the present study, 100 Lovibond’s depression, anxiety and stress scale (DASS-42) (1995) questionnaires and 100 Nordic questionnaires were provided to nurses. 90 of them filled these questionnaires and a total of 180 valid mental health and physical health questionnaires were collected. So, the response rate was 90%.

In the Nordic questionnaire, where age is considered as an interval, 46.67% had 20-30 years, 31.11% had 30-40 years and 22.22% had 40 years and more. Among the population under study, 53.8% were men and 46.2% were women, of which 53.9% were married and 46.1% were single. 28.9% of participants were from CCU, 24.4% from ICU and 46.7% from emergency department. Considering that increased work pressure, fatigue, body posture during activity and, working hours during the day can cause many mental and physical problems; this case was also examined in our study. It was found that 58.9% of Nurses work eight hours a day and 38.9% of them work more than ten hours a day. 3.7% of nurses were permanently sitting, 11.1% were permanently standing and 58.2% were doing their activities as standing and sitting. In addition to the fact that nurses are active during their working hours, 16.9% of them are also active outside of working hours. Due to the effect of exercise on mental and physical health, one of the sections of the questionnaire was about this issue that 22.4% of the participating nurses confirmed their sports activity.

In Table 1, the physical health problems inflicted on nurses were examined through the Nordic questionnaire, which shows how many nurses, equivalent to what percentage of the population, suffer from what injuries, and what percentage of nurses has been forced to reduce their work or go on leave due to severity of their pain. About 40% of the nurses had musculoskeletal pain.

Region	Number (Percentage) of people with pain	Decreased activity of physically injured nurses
Neck	17(%18.9)	%20.2
Shoulders	22(%24.4)	%22.5
Elbows	21(%23.3)	%16.9
Wrists/Hands	19(%21.1)	%18.0
Waist	23(%25.6)	%27.0
Thighs and hips	11(%12.2)	%6.7
Knees	15(%16.9)	%13.5
Upper back	21(%23.3)	%16.9
Feet	13(%14.6)	%12.5

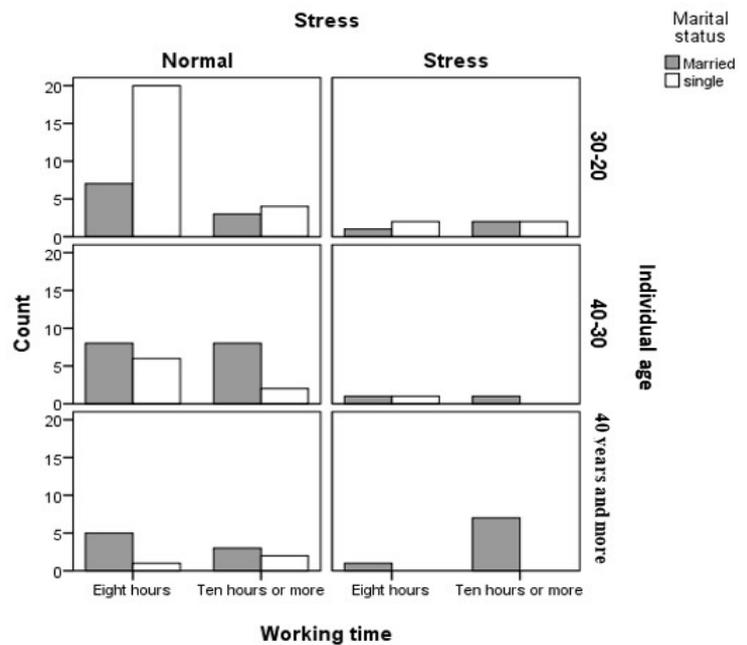


Figure 1. Investigating the relationship between mental health and physical health

Table 1. Evaluation of pain in nine parts of nurses' bodies

Table 2. Significance level for some questionnaire parameters with Spearman, Kruskal-Wallis and Mann-Whitney U tests

Criterion	Age	Marital status	Type of activity	Working time	Depression	Anxiety	Stress
Depression	0.022	—	—	0.004	—	—	—
Anxiety	0.013	—	—	0.011	—	—	—
Stress	0.008	0.04	—	0.007	—	—	—
Pains	—	0.007	0.003	0.000	0.012	0.000	0.002

Table 3.

Percentage

Pain area		Neck	Shoulders	Elbows	Wrists/Hands	Waist	Thighs and Hips	Knees	Upper back	Feet
Mental Injury	Normal	5.56	8.89	8.89	5.56	11.11	5.56	8.89	8.89	6.67
	Light	3.33	4.44	4.44	5.56	4.44	1.11	1.11	4.44	1.11
	Average	5.56	6.67	5.56	5.56	6.67	2.22	4.44	6.67	4.44
	Intense	4.44	4.44	4.44	4.44	3.33	3.33	2.22	3.33	2.22
	Very Intense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Depression	Normal	3.33	5.56	4.44	3.33	5.56	2.22	5.56	3.33	4.44
	Light	3.33	2.22	3.33	2.22	4.44	2.22	3.33	4.44	2.22
	Average	0.00	3.33	2.22	2.22	1.11	0.00	1.11	1.11	1.11
	Intense	5.56	6.67	6.67	6.67	7.78	4.44	4.44	7.78	4.44
	Very Intense	6.67	6.67	6.67	6.67	6.67	3.33	2.22	6.67	2.22
Anxiety	Normal	10.00	13.33	13.33	11.11	14.44	5.56	8.89	12.22	6.67
	Light	0.00	2.22	1.11	1.11	3.33	2.22	2.22	3.33	2.22
	Average	6.67	6.67	6.67	6.67	5.56	3.33	3.33	5.56	3.33
	Intense	2.22	2.22	2.22	2.22	2.22	1.11	1.11	2.22	1.11
	Very Intense	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Stress	Normal	10.00	13.33	13.33	11.11	14.44	5.56	8.89	12.22	6.67
	Light	0.00	2.22	1.11	1.11	3.33	2.22	2.22	3.33	2.22
	Average	6.67	6.67	6.67	6.67	5.56	3.33	3.33	5.56	3.33
	Intense	2.22	2.22	2.22	2.22	2.22	1.11	1.11	2.22	1.11
	Very Intense	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11

of people with both physical and mental health problems

Depression scale among nurses had a mean of 7.56 and a variance of 7.1. This scale was normal in 62.22% of nurses and showed symptoms of depression in 37.78% of them. Anxiety scale had a mean of 7.89 and a variance of 7.37 which was normal in 52.22% of nurses and showed symptoms of anxiety in 47.78% of them. The stress scale had a mean of 9.19 and a variance of 8.39

which was normal for 78.89% of nurses and 21.11% of them had some symptoms of stress.

Investigations have shown that there is a significant relationship between some parts of the study with the variables of depression, anxiety and stress. Table 2 shows this level of significance. The last

row of this table consists of pains. All nurses who feel pain in one of the parts identified in the Nordic questionnaire are included in this row. Other parameters that were questioned in the questionnaire, such as gender and sports activity, were not at a significant level with physical and mental health problems.

As can be seen in Table 2, there is a significant relationship between mental and physical health problems. Table 3 shows the percentage of nurses' exposure to mental health problems including depression, anxiety and stress by showing the severity of the disease and, to physical health problems in the Nordic questionnaire by showing the pain area.

Figure 1 examines nurses who have two or three mental and physical health problems. As it is obvious, 12.22% of nurses have all three cases of mental health problems as well as physical illnesses, but only 4.44% suffer from mental health problems and do not suffer from physical illnesses. Among the nurses, 52.22% had one of the problems of depression, anxiety and stress and also 65.17% of them had a mental or physical health problem which shows that only 34.83% of the nurses were in perfect health.

Discussion

Examining the mental health and physical health of nurses during the outbreak of COVID-19 disease has shown that about 40% of nurses have physical health problems and 52.22% of them have mental health problems. In terms of physical health, the most common affected part is the waist and then the shoulders. Nurses' mental health was not at the normal level, with anxiety and depression being more common, respectively, but there was less stress than depression and anxiety. 12.22% of the nurses had both mental and physical health problems and 16.66% of the nurses had all three mental health problems (depression, anxiety and stress). Mental health is related to age and working hours. In addition to these two, stress had also a significant relationship with marital status. Marital status, type of activity in workplace, working hours, depression, anxiety and stress were some of the factors related to nurses' physical health.

Three units of emergency, intensive care and coronary care were examined in this study. If nurses are not given enough time to

the interval of 30-40 years, and 14.45% of nurses in the interval of 40 years and more, had some symptoms of anxiety. The use of heavy protective equipment during work shifts and the difficulty of patient care are the most important causes of fatigue and anxiety in

rest during long shifts, they will be put under a lot of pressure, which can aggravate mental health problems. 41.6% of emergency department nurses, 50% of intensive care unit nurses and 20.8% of coronary care unit nurses work more than ten hours a day.

Physical health problems can in some cases lead to mental health problems. Musculoskeletal pain, as well as the fear of disability due to pain, is one of the factors that has caused mental health problems in nurses. Previous studies have confirmed that there is a strong relationship between mental and physical health.³ The correlation between physical and mental health problems is an important challenge in modern medicine that is influenced by various factors (Comorbidity of mental and physical diseases: a main challenge for medicine of the 21st century, 2013). Among nurses who feel pain in one part:

- 24.14% work ten hours or more per day and 14.94% work eight hours a day.
- Working activity takes place 25% as standing and sitting, 7.50% as permanently standing, and 2.50% as permanently sitting.
- 29.55% of these nurses are married and 10.23% are single.
- About 20% are depressed, 25.84% are anxious and 14.61% are stressed.

According to Table 1, a large number of nurses, despite the pain, cannot reduce their work activities and rest or go on leave. So, due to nursing shortage, they are forced to continue their activities despite the pain, which endangers both physical health and mental health of nurses. In Iran, the nurses-to-bed ratio is 7 to 8 tenths, which causes mandatory overtime. The shift of nurses has been changed to every-two-week shift and does not follow the previous normal shifts.²⁶

According to Table 2, working hours and age of nurses have a significant relationship with depression. 14.44% of nurses in the interval of 20-30 years, 8.89% of nurses in the interval of 30-40 years, and 12.23% of nurses in the interval of 40 years and more, had symptoms of depression, which 20% of them work more than ten hours a day. Excessive work, work shifts, resuscitation and death are some of the factors that have led to depression in nurses.²⁷ In our study, 21.12% of nurses in the interval of, 10% of nurses in

nurses.²⁸ Also, 23.35% of nurses with anxiety work more than ten hours a day. As shown in Figure 2, 7.87% of nurses in the interval of 20-30 years, 3.33% of nurses in the interval of 30-40 years, and 8.89% of nurses in the interval of 40 years and more, were stressed

which 13.33% of them worked more than ten hours a day. Considering the significant relationship between marital status and stress, it was found that 14.44% of stressed nurses are married. A significant relationship between the two was predictable due to nurses' exposure to illness, excessive work, frustration, fear, fatigue, and lack of contact with family.⁹

Mean and variance for depression, anxiety and stress do not have a normal norm, which indicates that nurses suffer from mental health problems. In a study conducted in China, the ratios of depression and anxiety during the outbreak of COVID-19 among nurses were 34.3% and 18.1%, respectively, and among nurses caring for patients infected with this disease, they were 47.1% and 28.4%, respectively. Their results showed that hospitals should consider programs to promote nurses' mental health.¹⁸ In addition, according to another study conducted in a population of 4,692 nurses in China, 442 nurses or 9.4% had symptoms of depression, 379 or 8.1% had symptoms of anxiety, so, the health of nurses during the outbreak of COVID-19 was determined as poor in this study.²⁹ There have been other studies that have proven otherwise and have shown that nurses experience positive effects like personal growth, sense of accomplishment, and better appreciation for life.^{30,31} But to improve nurses' current status, policies such as shorter shift lengths, making adequate personal protective equipment available, educating nurses in dealing with this virus, mental health, and support services can be carried out.³²

Anxiety and stress are common effects that occur when a person is in a critical situation. COVID-19 virus can cause mental health problems in patients due to its unknown nature.¹² Nurses work among the patients who are not in a good mental condition. As shown in Table 2, depression, anxiety and stress are at a significant level with different parameters. Previous studies have shown that the severity of symptoms of mental health problems depends on age, gender, type of activity, direct contact with infected patients, etc.² Identifying and diagnosing the symptoms of mental health problems during the outbreak of this virus is of particular importance³³ because these problems can have a negative impact on performance of nurses and prevent them from serving patients well.³⁴

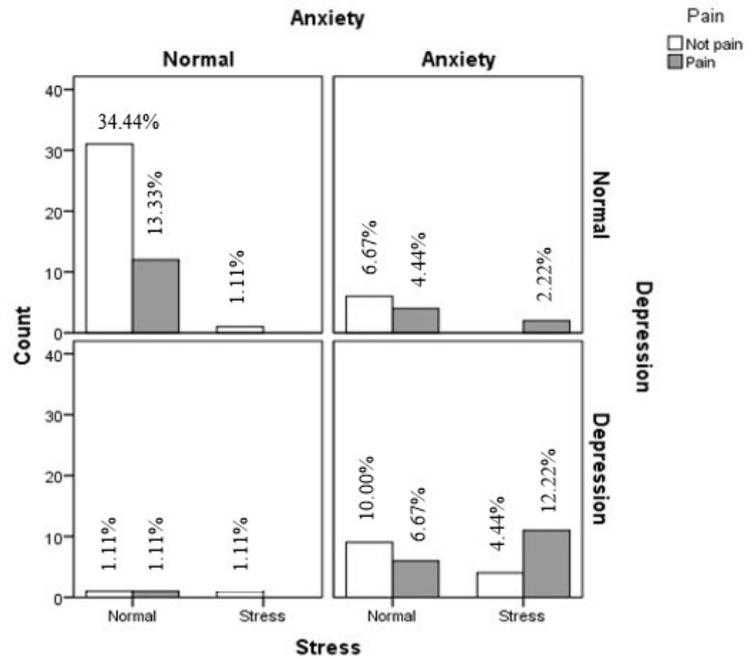


Figure 2. Significant relationship between stress and some other factors

Contrary to previous research that confirmed a positive relationship between exercise and reduced depression and anxiety, as well as mental health,^{35,36} this study found no relationship between exercise and depression, anxiety, stress, and musculoskeletal pain. The study of the relationship between exercise and mental health problems, a detailed study of the physical problems inflicted on nurses during the outbreak of COVID-19, and finally research on a larger sample of nurses are of the issues that require further research in this field.

Conclusion

During the outbreak of COVID-19 virus, nurses have suffered mental health problems, including depression, anxiety and stress, and many of them have suffered physical health problems. Mental health problems had a positive relationship with physical health problems, and it was concluded that mental health problems can aggravate musculoskeletal pain. Nurses' working hours have increased during the corona outbreak, which has caused mental and physical fatigue. The increase in working hours in the intensive care unit and emergency department was much larger than in the coronary care unit. Officials and the public are expected to take the consequences of COVID-19 virus seriously by considering the mental and physical consequences of similar infectious diseases in the past, and to look for ways and policies to reduce these factors, especially in patients and nurses. Carrying out health protocols is one of the convenient measures that can be done by everyone and can greatly prevent infection with this disease.

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Conflict of Interest Statement:

All nurses participated in this study with their own consent.

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References

- Lin M, Beliavsky A, Katz K, et al. What can early Canadian experience screening for COVID-19 teach us about how to prepare for a pandemic? *In Cmaj* . Published 2020; 192: 12: E314–E318. doi: 10.1503/cmaj.200305
- Khattak S, R Saeed, I Rehman, et al. Impact of Fear of COVID-19 Pandemic on the Mental Health of Nurses in Pakistan. *Journal of Loss and Trauma*. Published 2020; 0(0): 1–15. doi: 10.1080/15325024.2020.1814580
- Galehdar N, Kamran A, Toulabi T, et al. Exploring nurses' experiences of psychological distress during care of patients with COVID-19: A qualitative study. *BMC Psychiatry*. Published 2020. doi:10.1186/s12888-020-02898-1
- IRNA. Islamic Republic News Agency. 100 nurses died of coronary heart disease. announced 2020 December 17. <https://www.irna.ir/news/84151681/>
- Ramaci T, Barattucci M, Ledda C, et al. Social stigma during COVID-19 and its impact on HCWs outcomes. Published 2020. *Sustainability (Switzerland)*. doi:10.3390/su12093834
- Zhu Z, Xu S, Wang H, et al. COVID-19 in Wuhan: Immediate Psychological Impact on 5062 Health Workers. *EClinicalMedicine*. Published 2020. doi: 10.1101/2020.02.20.20025338
- Zhou Q, Lai X, Wa, Z, et al. Impact of burnout, secondary traumatic stress and compassion satisfaction on hand hygiene of healthcare workers during the COVID-19 pandemic. *Nursing Open*. Published 2021; 1–16. doi.org/10.1002/nop2.786
- Lai J, Ma S, Wang, et al. Factors Associated With Mental Health Outcomes Among Health Care Workers Exposed to Coronavirus Disease 2019. *JAMA Network Open*. 2020; 3(3): e203976. doi: 10.1001/jamanetworkopen.2020.3976
- Kang L, Li Y, Hu S, et al. The mental health of medical workers in Wuhan, China dealing with the 2019 novel coronavirus. *In The Lancet Psychiatry*. 2020; 7(3): e14. doi: 10.1016/S2215-0366(20)30047-X
- Boyle D. Countering compassion fatigue: a requisite nursing agenda. *In Online journal of issues in nursing*. Published 2011. doi: 10.3912/OJIN.Vol16No01Man02
- Mo Y, Deng L, Zhang L, et al. Work stress among Chinese nurses to support Wuhan in fighting against COVID-19 epidemic. *Journal of Nursing Management*. 2020; 28(5): 1002–1009. doi: 10.1111/jonm.13014
- Zandifar A, Badrfam R, Yazdani S, et al. Prevalence and severity of depression, anxiety, stress and perceived stress in hospitalized patients with COVID-19. *Journal of Diabetes and Metabolic Disorders*. 2020; 19: 1431–1438. doi.org/10.1007/s40200-020-00667-1
- Nemati M, Ebrahimi B, Nemati F. Assessment of iranian nurses' knowledge and anxiety toward covid-19 during the current outbreak in iran. *Archives of Clinical Infectious Diseases*. Received 2020 March 18; Accepted 2020 March 24. doi: 10.5812/archcid.102848
- Pouralizadeh M, Bostani Z, Maroufizadeh S, et al. anxiety and depression and the related factors in nurses of Guilan University of Medical Sciences hospitals during COVID-19: A web-based cross-sectional study. *International Journal of Africa Nursing Sciences*. Accepted 3 August 2020. doi: 10.1016/j.ijans.2020.100233
- Said R, El-Shafei D. Occupational stress, job satisfaction, and intent to leave: nurses working on front lines during COVID-19 pandemic in Zagazig City, Egypt. *Environmental Science and Pollution Research*. 2021; 28: 8791–8801 doi: 10.1007/s11356-020-11235-8
- Gu B, Tan Q, Zhao S. The association between occupational stress and psychosomatic wellbeing among Chinese nurses: A cross-sectional survey. *Medicine (United States)*. 2019; 98(22): 1–6. doi: 10.1097/MD.00000000000015836
- 19 in China: A cross-sectional study. *International Journal of Nursing Studies*. 2021; 114: 103809. doi: 10.1016/j.ijnurstu.2020.103809
- Halbreich U, Kahn L. Atypical depression, somatic depression and anxious depression in women: Are they gender-preferred phenotypes? *Journal of Affective Disorders*. 2007; 102(1–3): 245–258. doi: 10.1016/j.jad.2006.09.023
- Huang Y, Zhao N. Generalized anxiety disorder, depressive symptoms and sleep quality during COVID-19 outbreak in China: a web-based cross-sectional survey. *Psychiatry Research*. 2020; 288: 112954. doi: 10.1016/j.psychres.2020.112954
- Zheng R, Zhou Y, Fu Y, et al. Prevalence and associated factors of depression and anxiety among nurses during the outbreak of COVID-

20. Lu D, Sun N, Hong S, et al. Occupational Stress and Coping Strategies Among Emergency Department Nurses of China. *Archives of Psychiatric Nursing*. 2015; 29(4): 208–212. doi: 10.1016/j.apnu.2014.11.006
21. Healy S, Tyrrell M. Stress in emergency departments: Experiences of nurses and doctors. *Emergency Nurse*. 2011; 19(4): 31–37. doi: 10.7748/en2011.07.19.4.31.c8611
22. An Y, Yang Y, Wang A, et al. Prevalence of depression and its impact on quality of life among frontline nurses in emergency departments during the COVID-19 outbreak. *Journal of Affective Disorders*. Accepted 30 June 2020 . doi: 10.1016/j.jad.2020.06.047
23. Lovibond P, Lovibond H. The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour Research and Therapy*. Accepted 22 September 1994. doi: 10.1016/0005-7967(94)00075-U
24. Afzali A, Delavar A, Borjali A, et al. Psychometric Properties of DASS-42 as Assessed in a Sample of Kermanshah High School Students. *Journal of research in behavioural sciences*. 2007; 5(2): 81–91.
25. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied Ergonomics*. 2003; 18(3): 233–237. doi: 10.1016/0003-6870(87)90010-X
26. Eghtesadonline. Endangering the job security of nurses with 89-day contracts (2020). <https://www.google.com/amp/s/www.eghtesadonline.com/fa/amp/news-490808>
27. Morrison L, Joy P. Secondary traumatic stress in the emergency department. *Secondary traumatic stress in the emergency department*. 2016; 72(11): 2894–2906. doi: 10.1111/jan.13030
28. Liu C Y, Yang Y Z, Zhang X M, et al. The prevalence and influencing factors for anxiety in medical workers fighting COVID-19 in China: A cross-sectional survey. *MedRxiv*. May 2020. doi: 10.1101/2020.03.05.20032003
29. Hong S, Ai M, Xu X, et al. Immediate psychological impact on nurses working at 42 government-designated hospitals during COVID-19 outbreak in China: A cross-sectional study. *Nursing Outlook*. 2021; 1–7. doi: 10.1016/j.outlook.2020.07.007
30. Rubin G J, Harper S, Williams P D, et al. How to support staff deploying on overseas humanitarian work: A qualitative analysis of responder views about the 2014/15 West African Ebola outbreak. *European Journal of Psychotraumatology*. Accepted 15 Oct 2016. doi: 10.3402/ejpt.v7.30933
31. West C, Bernard B, Mueller C, et al. Mental health outcomes in police personnel after Hurricane Katrina. *Occupational and Environmental Medicine*. 2008; 50(6): 689–695. doi: 10.1097/JOM.0b013e3181638685
32. Shaukat N, Ali D M, Razzak J. Physical and mental health impacts of COVID-19 on healthcare workers: A scoping review. *International journal of Emergency Medicine*. Published 20 July 2020. doi: 10.1186/s12245-020-00299-5
33. Xiang Y T, Yang Y, Li W, et al. Timely mental health care for the 2019 novel coronavirus outbreak is urgently needed. *In The Lancet Psychiatry*. Published February 04 2020. doi: 10.1016/S22150366(20)30046-8
34. Johnson J, Hall L H, Berzins K, et al. Mental healthcare staff well-being and burnout: A narrative review of trends, causes, implications, and recommendations for future interventions. *Mental Health Nursing*. 2017; 27(1), 20–32. doi: 10.1111/inm.12416
35. Oláh K. The influence of binarity on stellar activity. *Proceedings of the International Astronomical Union*. 2007; 2(S240): 442–452. doi: 10.1017/s1743921307004425
36. Harris A H S, Cronkite R, Moos R. Physical activity, exercise coping, and depression in a 10-year cohort study of depressed patients. *Journal of Affective Disorders*. 2006; 93(1–3), 79–85. doi: 10.1016/j.jad.2006.02.013

Interactive IoT-Blockchain System for Big Data Processing

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Abstract

The spectrum of IoT devices is becoming widely diversified, entering almost all possible fields and finding applications in industry, health, finance, logistics, education, to name a few. The IoT active end point sensors and devices exceeded the 12 billion mark in 2021 and expected to reach 27 billion in 2025, with over \$34 billion in total market value. This sheer rise in numbers and use of IoT devices bring with it considerable concerns regarding data storage, analysis, manipulation and protection. IoT Blockchain-based systems have recently been proposed as a decentralized solution for large scale data storage and protection. COVID-19 has actually accelerated the desire to utilize IoT devices as it impacted both demand and supply and significantly affected several regions due to logistic reasons such as supply chain interruptions, shortage of shipping containers and port congestion.

An IoT-blockchain system is proposed to handle big data generated by a distributed network of sensors and controllers in an interactive manner. The system is designed using Ethereum platform which utilizes smart contracts, programmed in solidity, to execute and manage data generated by IoT sensors and devices. such as Raspberry Pi 4, Rasbpian, and add-on hardware security modules. The proposed system will run a number of applications hosted by a local machine used to validate transactions. It then sends data to rest of the network through Inter Planetary File System (IPFS) and Ethereum Swarm, forming a closed IoT ecosystems run by blockchain where a number of distributed IoT devices can communicate and interact, thus forming a closed controlled environment. A prototype has been deployed with three IoT handling units distributed over a wide geographical space in order to examine its feasibility, performance and costs. Initial results indicated that big IoT data retrieval and storage is feasible and interactivity is possible, provided that certain conditions of cost, speed and thorough put are met.

Keywords: IoT Devices, Blockchain, Ethereum, Big Data

References

- [1] Xiaochen Zheng, Jinzhi Lu, Shengjing Sun and Dimitris Kiritsis, "Decentralized Industrial IoT Data Management Based on Blockchain and IPFS", *Advances in Production Management Systems: Towards Smart and Digital Manufacturing*, pp 222-229, 2020. https://doi.org/10.1007/978-3-030-57997-5_26.
- [2] Ma Zhaofeng, Member, IEEE, Wang Lingyun, Wang Xiaochang, Wang Zhen, and Zhao Weizhe, "Blockchain-Enabled Decentralized Trust Management and Secure Usage Control of IoT Big Data", *IEEE Internet of Things Journal*, pp. 4000-4015, Vol. 7, No. 5, May 2020. <https://doi.org/10.1109/JIOT.2019.2960526>.

- [3] Steven A. Wright, "Privacy in IoT Blockchains: with Big Data Comes Big Responsibility", 2019 IEEE International Conference on Big Data, Los Angeles, USA, 9-12 December 2019. <https://doi.org/10.1109/BigData47090.2019>.
- [4] Zi Ee Lee, Raphael Liang Hui Chua, Sye Loong Keoh and Yoshihiro Ohba, "Performance Evaluation of Big Data Processing at the Edge for IoT-Blockchain Applications", IEEE Global Communications Conference (GLOBECOM), Waikoloa, USA, 9-13 December 2019. <https://doi.org/10.1109/GLOBECOM38437.2019>.
- [5] Ana Reyna, Cristian Martín, Jaime Chen, Enrique Soler and Manuel Díaz, "On Blockchain and its Integration with IoT. Challenges and Opportunities", Future Generation Computer Systems, Vol. 88, pp. 173-190, 2018. <https://doi.org/10.1016/j.future.2018.05.046>.

Challenges of Blockchain Applications in the Supply Chain Industry: A Regulatory Perspective

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Abstract— Due to the emergence of blockchain technology and the benefits of cryptocurrencies, intelligent or smart contracts are gaining traction. Artificial intelligence (AI) is transforming our lives, and it is being embraced by a wide range of sectors. Smart contracts, which are at the heart of blockchains, incorporate AI characteristics. Such contracts are referred to as "smart" contracts because of the underlying technology that allows contracting parties to agree on terms expressed in computer code that defines machine-readable instructions for computers to follow under specific situations. The transmission happens automatically if the conditions are met. Initially utilised for financial transactions, blockchain applications have since expanded to include the financial, insurance, and medical sectors, as well as supply networks. Raw material acquisition by suppliers, design, and fabrication by manufacturers, delivery of final products to consumers, and even post-sales logistics assistance are all part of supply chains. Many issues are linked with managing supply chains from the planning and coordination stages, which can be implemented in a smart contract in a blockchain due to their complexity. Manufacturing delays and limited third-party amounts of product components have raised concerns about the integrity and accountability of supply chains for food and pharmaceutical items. Other concerns include regulatory compliance in multiple jurisdictions and transportation circumstances (for instance, many products must be kept in temperature-controlled environments to ensure their effectiveness). Products are handled by several providers before reaching customers in modern economic systems. Information is sent between suppliers, shippers, distributors, and retailers at every stage of the production and distribution process. Information travels more effectively when individuals are eliminated from the equation. The usage of blockchain technology could be a viable solution to these coordination issues. In blockchains, smart contracts allow for the rapid transmission of production data, logistical data, inventory levels, and sales data. This research investigates the legal and technical advantages and disadvantages of AI-blockchain technology in the supply chain business. It aims to uncover the applicable legal problems and barriers to the use of AI-blockchain technology to supply chains, particularly in the food industry. It also discusses the essential legal and technological issues and impediments to supply chain implementation for stakeholders, as well as methods for overcoming them before releasing the technology to clients. Because there has been little research done on this topic, it is difficult for industrial stakeholders to grasp how blockchain technology could be used in their respective operations. As a result, the focus of this research will be on building advanced and complex contractual terms in supply chain smart contracts on blockchains to cover all unforeseen supply chain challenges.

Keywords— blockchain, supply chain, IoT, smart contract.

Effect of Sand Particle Distribution in Oil and Gas Pipeline Erosion

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Abstract— Erosion in a pipe bends caused by particles is a major obstacle in the oil and gas fields and might cause breakdown to production equipment. This work studied the effects imposed by flow velocity and impact of solid particles diameter in an elbow, erosion rate was verified with experimental data using computational fluid dynamics (CFD) approach. Two-way coupled Euler-Lagrange and discrete phase model was employed to calculate the air/ solid particle flow in an elbow. One erosion model and three particle rebound models were used to predict the erosion rate on the 90° elbows. The generic erosion model, was used in CFD-based erosion model and after comparing with experimental data result showed agreement with the CFD-based predictions as observed.

Keywords— Erosion, Prediction, Elbow, computational fluid dynamics (CFD)

INTRODUCTION

Sand production in oil and gas pipeline is a significant concern to the industry, which may jeopardise equipment performance leading to failure. As a prevalent component in pipeline infrastructure, 90° elbow are used to change flow direction in pipelines. Rapid deviation in direction of flow can produce huge change in distribution of sand particles. studies have shown that erosion on a pipeline with high pressure usually occur in an elbow and the mass loss rate due to particle impingement may be fifty times higher than mass loss in straight pipe.[1] In recent time, numerous erosion mechanism and theoretical model have been recommended[2]; an equation for erosional calculation of elbow was given by American Petroleum Institute (API-14E) criterion which examine particle velocity and quantities, [3] Tilly [4] examine material density and recommended a method for erosion rate calculation. Salama. [5] recommended a modify equation for calculating erosion rate on particle size and mixture density. Zhang et al. [6] consider the flow field during computing of particle erosion in air and water flow, and Chen et al. [7] suggested a technique to assess erosion rate in multiphase flow which is centred on numerical simulation and mechanistic evaluation. Therefore, it is essential to obtain an effective method of predicting the erosion distribution around an elbow which is important for the integrity of pipeline management. Furthermore, the accurate prediction of erosion rate makes it simpler to find erosion hotspot and allow for the evaluation of service life of pipe. A lot of experimental work have been done previously to investigate particle erosion in elbows [8] most of the experiments were conducted to examine the maximum erosion rate of an elbow and the continuous erosion profile about the elbow. This paper will address the use of a computational fluid dynamics (CFD) methodology to predict the location of erosion hotspots in a 90° elbow. The Eulerian-Lagrangian approach for continuous and discrete phase

calculations with different turbulence models has been implemented to investigate the importance of erosion mechanisms in pipe elbows.

I. SIMULATION

A. Modeling

There three main steps in CFD-based erosion modelling: the continuous phase simulation flow field, tracking of particle and calculation of erosion rate. In present work the fluid phase is treated as a continuous phase and is solved by the Navier-Stokes governing equation. The sand particles are treated as discrete phase and are solved by Newton's second law motion. In addition, two-way coupling are employed between the continuous phase and discrete phase.

B. The continuous phase models

The Navier-Stokes equations are employed here. The general equations of continuity and momentum are given:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho \vec{u}) = 0 \quad (1)$$

$$\frac{\partial}{\partial t}(\rho \vec{u}) + \nabla \cdot (\rho \vec{u} \vec{u}) = -\nabla P + \nabla \cdot (\vec{\tau}) + \rho \vec{g} + \vec{S}^m \quad (2)$$

where ρ is fluid density, \vec{u} is instantaneous velocity vector of fluid, P is the static pressure, $\vec{\tau}$ is the stress tensor, $\rho \vec{g}$ is the body force, \vec{S}^m is the additional momentum due to discrete phase. The stress tensor are given:

$$\vec{\tau} = \mu \left[(\nabla \vec{u} + \nabla \vec{u}^T) - \frac{2}{3} \nabla \cdot \vec{u} I \right] \quad (3)$$

where μ is viscosity of fluid, I is unit tensor. The turbulence model standard k- omega with SST are used in this work to calculate the flow turbulence, equations as given:

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k u_i)}{\partial x_i} = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k - \rho \epsilon + S_k \quad (4)$$

$$\frac{\partial(\rho \epsilon)}{\partial t} + \frac{\partial(\rho \epsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_i} \left[\left(\mu + \frac{\mu_t}{\sigma_\epsilon} \right) \frac{\partial \epsilon}{\partial x_i} \right] + C_{1\epsilon} \frac{\epsilon}{k} G_k - C_{2\epsilon} \rho \frac{\epsilon^2}{k} + S_\epsilon \quad (5)$$

where G_k is the generation of turbulence kinetic energy due to mean velocity gradients, u_i is the velocity component in the i direction, x_i and x_j are the spatial coordinates, σ_k and σ_ϵ are turbulent Prandtl numbers for k and ϵ , $C_{1\epsilon}$ and $C_{2\epsilon}$ are constants, S_k and S_ϵ are source terms, $\mu_t = \rho C_\mu \frac{k^2}{\epsilon}$, $\sigma_k = 1.0$, $\sigma_\epsilon = 1.3$, $C_{1\epsilon} = 1.44$, $C_{2\epsilon} = 1.92$, $C_\mu = 0.09$.

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C. discrete / dispersed phase model

The discrete/dispersed phase model is employed, in which particle trajectories is acquired by integrating the motion equation of particles under the Lagrangian coordinates. The governing equation of particle motion of the fluid according to Newton's second law:

$$\frac{d\vec{u}_p}{dt} = \vec{F}_D + \vec{F}_P + \vec{F}_B + \vec{F}_c \quad (6)$$

From the first term $\vec{F}_D, \vec{F}_P, \vec{F}_B$, and \vec{F}_c in equ. (6) representing the drag force, the pressure gradient force and the added mass force and the buoyancy force. the main hydrodynamic force that acts on particles is the drag force:

$$\vec{F}_D = \frac{18\mu}{\rho_p d_p^2} \frac{C_d Re_p}{24} (\vec{u} - \vec{u}_p) \quad (7)$$

where \vec{u} is particle velocity vector, d_p is particle diameter, ρ_p is density of particles, Re_p is particle Reynolds number:

$$Re_p = \frac{\rho d_p |\vec{u}_p - \vec{u}|}{\mu} \quad (8)$$

C_d the coefficient of drag

$$C_d = a_1 + \frac{a_2}{Re_p} + \frac{a_3}{Re_p^2} \quad (9)$$

where a_1, a_2, a_3 are constants for smooth spherical particles, and the three particle parameters differs with the Reynolds number. The pressure gradient force is caused by the pressure change in the flow

$$\vec{F}_P = \left(\frac{\rho}{\rho_p} \right) \nabla P \quad (10)$$

The virtual mass force is given as:

$$\vec{F}_B = \frac{1}{2} \frac{\rho d(\vec{u} - \vec{u}_p)}{\rho_p dt} \quad (11)$$

The buoyancy force is given as:

$$\vec{F}_A = \frac{(\rho_p - \rho)}{\rho_p} \vec{g} \quad (12)$$

In this work the particles are small, pressure change over distance of particle diameter is negligible. consequently, the density of fluid is much lower than the density of the particles, the pressure gradient force can be neglected. As the virtual mass force is important only when the fluid density is larger than the particles density, the virtual mass force can also be neglected.

D. Mechanism of Coupling between two phases

To achieve precise particle trajectories and erosion distributions, the coupling between two phase are considered, the continuous phase and the dispersed phase is especially in the conditions that the particle mass loading rate is high or the particle collision is intense

E. Coupling of Momentum

The momentum exchange is computed by examining the change of the particle momentum when it passes through each control volume, which is expressed as

$$S_M = \sum (F_D + F_A) M_p \nabla t \quad (13)$$

where M_p is referred to as mass flow rate of particles, ∇t is referred to as the time step.

F. Coupling of Turbulence

Stochastic is a tracking method used to predict the effect of turbulent flow fluctuations on particle trajectories. The dispersion of particles in the fluid phase turbulence is calculated using discrete random walk (DRW) model, which use the instantaneous fluid velocity to incorporate the trajectory given by:

$$u = \bar{u} + u'(t) \quad (14)$$

The turbulent fluctuating velocity that retain Gaussian probability distribution is as follows:

$$u' = \zeta \sqrt{u'^2} \quad (15)$$

where ζ referred to random number which obeys normal distribution. And if, the local turbulence is isotropic, then the local root mean square (RMS) value of the velocity fluctuation is calculated by the following

$$\sqrt{u'^2} = \sqrt{\frac{2k}{3}} \quad (16)$$

Production of turbulent eddies causes particle damping and this turbulence eddies can alter the turbulent quantities. Equation (4) and (5) added particle source terms effect into account and the fluid phase turbulent kinetic energy has been modified by the formulation expressed in [9] and [10].

II. PARTICLE-PARTICLE-WALL/ RESTITUTION COEFFICIENT BEHAVIOR

In CFD code, particle-wall restitution coefficient rebound model is used with erosion model to predict the dynamic particle movement, erosion rate and erosion location. However, several restitution coefficients have been suggested to describe the effect of restitution coefficient and particle rebound behavior [11][12][13] In this study, three models are used which are derived experimentally, Forder et al. [13] particle-wall rebound model, Grant and Tabakoff [11] particle-wall rebound model and Sommerfeld and Huber [12] restitution coefficient model with the erosion prediction models to track particles and predict erosion. The restitution of coefficient e_c of normal direction and restitution of coefficient e_{par} of tangential direction which represent change in particle velocity due to impact on the wall. Forder et al. [13] suggested the following coefficient correlation for perpendicular and parallel velocity of the components for AISI 4130:

$$e_c = 0.988 - 0.78\alpha + 0.19\alpha^2 - 0.024\alpha^3 + 0.0027\alpha^4 \quad (17)$$

$$e_{par} = 1 - 0.78\alpha + 0.84\alpha^2 - 0.21\alpha^3 + 0.028\alpha^4 - 0.022\alpha^5 \quad (18)$$

where α is angle of particle incidence. Suggested model coefficient developed by Grant and Tabakoff [11] is as follows:

$$e_c = 0.993 - 1.76\alpha + 1.56\alpha^2 - 0.49\alpha^3 \quad (19)$$

$$e_{par} = 0.998 - 1.66\alpha + 2.11\alpha^2 - 0.67\alpha^3 \quad (20)$$

Sommerfeld and Huber [12] suggested a model for the normal restitution of coefficient. the relationship for normal coefficient of restitution is as follows:

$$e_c = \max(1 - 0.013\alpha, 0.7) \quad (21)$$

III. EROSION MODEL

In predicting erosion in an elbow several factors need to be consider, such as impact angle and impact speed. These factors are considered as the particles impinges on pipe and elbow geometry wall. Using this factors the rate of erosion is then calculated. The rate of erosion can be described as mass loss of pipe wall by erosion divided by mass of impinging particle on the wall. consequently, erosion rate is dependent on the particle impact angle and impact velocity and mass flow rate. However, in this work the generic model is used to calculate the erosion rate in the 90° elbow and the model is embedded in Ansys fluent given as follows:

$$ER = \sum_{p=1}^{N_{traj}} \frac{m_p C(d_p) f(\alpha) v_p^n}{A_f} \quad (22)$$

where C stands for the material wall constant, F_s stands for the particle shape, which is considered with exponent values of 0.2, 0.53 and 1 for semi-rounded, rounded, and sharp particles, respectively. V_p stands for the impact velocity and $f(\alpha)$ stands for the impact angle function. Impact velocity exponent is an empirical constant

$$f(\alpha) = \begin{cases} a\theta^2 + b\theta; & \theta \leq \theta_0 \\ x\cos^2(\theta)\sin(w\theta) + y\sin^2\theta + z; & \theta > \theta_0 \end{cases} \quad (23)$$

IV. COMPUTATIONAL FLUID DYNAMICS (CFD) MODELLING

A. Description of test case

A commercial software was adopted (ANSYS FLUENT) to perform a numerical simulation. An experiment data which was adopted by Peng W and Cao X [8] was employed in this study to examine the performed erosion models. The adopted experiment in Peng W and Cao X [8] examined the erosion rate of long radius elbows of a pneumatic transport system. A 90-degree elbow was used as test piece with 25.4mm diameter and a curvature radius of 38.1mm, which is shown in see Table1. A straight pipe length connect upstream to an elbow were evaluated for a better way of representing the flow at the test specimen location. The simulation was ran trying to replicate the same conditions as the one under which the experiment was done. See Table1. Consequently, in this study, a $20d = 810\text{mm}$ vertical pipe upstream and a $10d = 410\text{mm}$ horizontal pipe downstream of the elbow is used, which can be seen in Fig. 1.

TABLE I
SUMMARY OF FLOW CONDITIONS IN [8]

Names	Value
Fluid	Air
Velocity	25.24 m/s
Particle diameter	100 μm
Mass flow rate (Particles)	0.0286 kg/m^3
Density of Particles	2650 kg/s
Pipe Material density (Steel)	7800 kg/m^3
Brinell Hardness (BH)Material	120

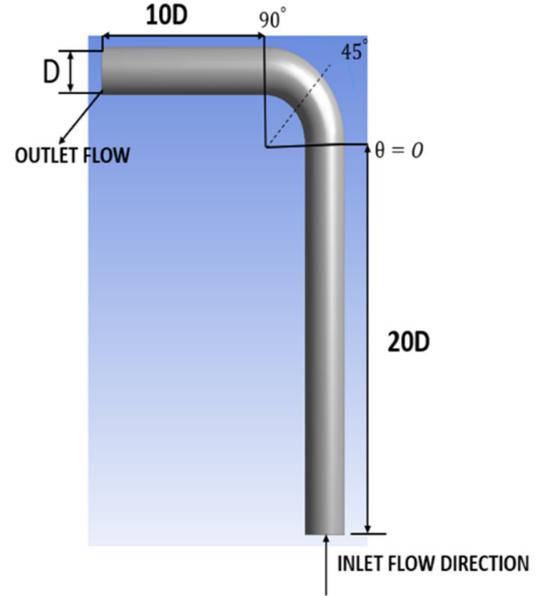


Fig. 1 Elbow geometry for simulation

B. Computational mesh

A 3-D computational hexahedral structured mesh was adopted in this simulation. The mesh surface was generated carefully due to the significant effect on quality of resulting mesh volume. A refinement near-wall region was done, in a high velocity gradients region and boundary layer was present. A structured hexahedral grid is used to mesh the surface of the cross-section. See Fig 2. The grid number used in this case is approximately 12,60793.

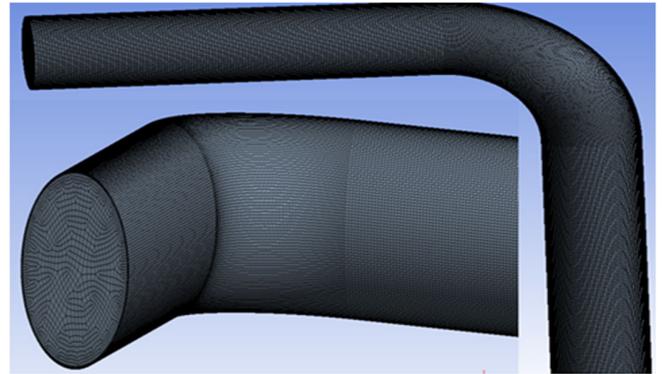


Fig 2. Structure mesh use for simulation

C. Boundary condition parameters

A sand particle were uniformly injected at the inlet of the pipe with the same velocity as the fluid. The particles injected are spherical in shape. parameter of roughness position is 0 that means the domain of the walls are smooth, and roughness constant is in the default value of 0.5. In addition, turbulence intensity position is 5%.

D. Numeric Method

The Coupled procedures were used for velocity and pressure coupling. discretization strategy was employed for pressure conditions and the second order discretization strategy was employed for divergence and convection conditions, also convergent benchmark used for calculations in the residual control volume for each of the equation is place as 0.0001, energy equation is 10^{-6} and number of the iterations set is 2000 in a simulation of steady state. However,

number of iterations for discrete phase model (DPM) is place as 10.

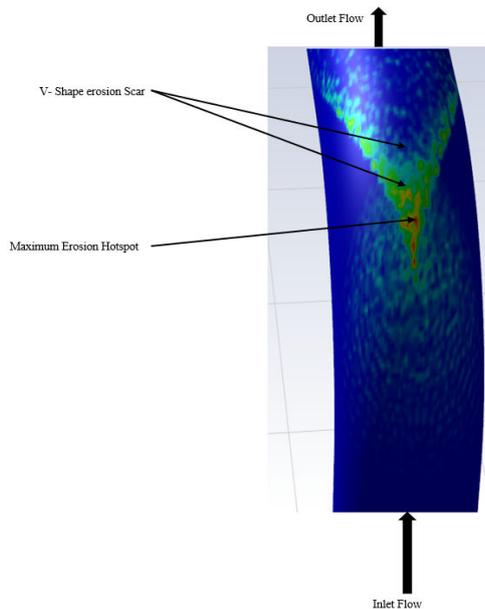


Fig. 3 Elbow Erosion Contour for simulation

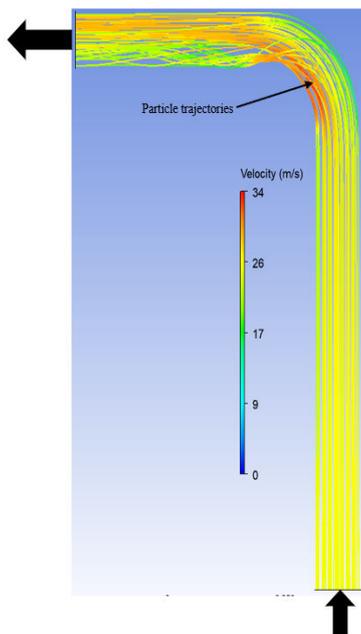


Fig. 4 Particle Trajectories

V. RESULTS AND DISCUSSION

Fig. 3 erosion contour and Fig. 4 particle trajectories shown the effect of velocity on erosion distributions and profile of the flow field in the elbows under the inlet velocity of 25.24m/s and the computational fluid dynamic (CFD) result shown in Fig. 3. the effect of increase in flow velocity due to the sand particles impinging on the wall of the elbow at high velocity and a point on the pipe elbow were observed to have started turning red due to velocity increase and the maximum erosion locations occur at 45° which is in good agreement with the experimental data of Peng W and Cao X [8]

CONCLUSION

In this work, Euler-Lagrange with k- ω turbulent model is applied to treat the air and solid particle as continuous phases and the discrete phase was employed to simulate particles trajectories. Then, analysis was conducted on the effects imposed by flow velocity and impact of solid particles diameter, the elbow erosion rate was verified with experimental result in Peng W and Cao X [8]. The conclusion is as follows: The exponential increase of erosion rate is caused by the increase of flow velocity and for small size particles, erosion gravitate to occur inside the elbow wall under the influence of inferior flow and for large particle size, the erosion gravitates to occur in the outer most part of elbow wall this is because of the inertial force acting on it.

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REFERENCES

- [1] Lin, N., Lan, H., Xu, Y., Dong, S., and Barber, G., 2015, "Effect of the Gas-Solid Two-Phase Flow Velocity on Elbow Erosion," *Journal of Natural Gas Science and Engineering*, **26**, pp. 581–586.
- [2] Huang, C., Mineev, P., Luo, J., and Nandakumar, K., 2010, "A Phenomenological Model for Erosion of Material in a Horizontal Slurry Pipeline Flow," *Wear*, **269**(3–4), pp. 190–196.
- [3] American Petroleum Institute, 1991, *API Recommended Practice 14E Design and Installation of Offshore Production Platform Piping Systems*.
- [4] Tilly, G. P., 1979, "Erosion Caused by Impact of Solid Particles," **13**, pp. 287–319.
- [5] Salama, M. M., 2000, "An Alternative to Api 14e Erosional Velocity Limits for Sand-Laden Fluids," *Journal of Energy Resources Technology, Transactions of the ASME*, **122**(2), pp. 71–77.
- [6] Zhang, Y., Reuterfors, E. P., McLaury, B. S., Shirazi, S. A., and Rybicki, E. F., 2007, "Comparison of Computed and Measured Particle Velocities and Erosion in Water and Air Flows," *Wear*, **263**(1-6 SPEC. ISS.), pp. 330–338.
- [7] Chen, X., McLaury, B. S., and Shirazi, S. A., 2006, "A Comprehensive Procedure to Estimate Erosion in Elbows for Gas/Liquid/Sand Multiphase Flow," *Journal of Energy Resources Technology, Transactions of the ASME*, **128**(1), pp. 70–78.
- [8] Peng, W., and Cao, X., 2016, "Numerical Prediction of Erosion Distributions and Solid Particle Trajectories in Elbows for Gas-Solid Flow," *Journal of Natural Gas Science and Engineering*, **30**, pp. 455–470.
- [9] Faeth, G. M., 1986, "Spray Atomization and Combustion," *AIAA*, **. 86-0136**, pp. 1–17.
- [10] Amsden, A., O'Rourke, P., and Butler, T., 1989, *KIVA-II: A Computer Program for Chemically Reactive Flows with Sprays*.
- [11] Grant, G., and Tabakoff, W., 1975, "Erosion Prediction in Turbomachinery Resulting from Environmental

- Solid Particles,” *Journal of Aircraft*, **12**(5), pp. 471–478.
- [12] Sommerfeld, M., and Huber, N., 1999, “Experimental Analysis of Modelling of Particle-Wall Collisions,” *International Journal of Multiphase Flow*, **25**(6–7), pp. 1457–1489.
- [13] Forder, A., Thew, M., and Harrison, D., 1998, “A Numerical Investigation of Solid Particle Erosion Experienced within Oilfield Control Valves,” *Wear*, **216**(2), pp. 184–193.

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Numerical Analysis of Shale Gas Production from Dendritic-Like Fractures Considering Complex Gas Flow and Transfer Mechanisms

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ABSTRACT

Multistage hydraulic fracturing (MSHF) of horizontal wells is a crucial technique of stimulation of naturally-fractured reservoirs (NFR). Because of the impact of the in-situ stress and natural fractures, the induced hydraulic fractures usually deviate from the primary hydraulic fractures (PHF) to create secondary hydraulic fractures (SHF), which usually advance at an angle to form complex multi-branched fractures. Micro-seismic events (MSE) indicate the dendritic-like geometry of hydraulic fractures in shale reservoirs which implies that conventional planar fracture models are not accurate enough to predict gas flow and production. In this study, we consider the embedded discrete fracture network (EDFN) to establish a computational method for accurately predicting gas production from a multi-angled-dendritic-like-fractured horizontal well using the finite element method (FEM). We capture complex gas transfer and flow mechanisms from matrix to fracture to the production well. The model is validated against conventional bi-wing fractures and field production data from a typical shale reservoir. Results of the proposed model indicate better performance over conventional bi-wing fractures and accurately match field data from Barnett shale. The angle and geometry of the fracture have a significant impact on overall gas production. Meanwhile, higher stress sensitivity coefficient reduces overall production. This paper provides a benchmark for understanding flow through dendritic-like fractures and deformation.

Keywords: Dendritic-like fractures; Multiscale flow; Secondary hydraulic fractures; Fracture geometry; Shale gas production.

1. Introduction

Shale gas reservoirs have received enormous attention due to the increased demand for natural gas that has continuously dropped from conventional reservoirs [1]-[3]. Shale reservoirs have recently been exploited using horizontal well drilling and hydraulic fracturing which are two techniques that allow wide coverage of the stimulated reservoir volume (SRV) and increase the amount of contact area allowing for improved production [4], [5]. In practice, a horizontal well is usually drilled parallel to

the direction of the minimum horizontal stress since that is the direction in which hydraulic fractures are perpendicularly formed [6]-[8]. During the process of horizontal well drilling, bi-wing fractures are created that usually connect with the pre-existing natural fractures to form a complex fracture network that acts as the flow path for gas [5]. Most studies have analyzed these bi-wing fractures through both numerical simulation and experiments [7], [8], [9] and the findings accruing from these studies have enabled the overall exploitation of shale gas reservoirs. However, due to the pre-existing natural fractures and unpredictable catastrophes like faults, fracture geometry in shale reservoirs is usually more complex and beyond the scope of simple bi-wing fractures [10]-[12].

Studies from laboratory experiments and images from geological outcrops indicate that fractures are overlapping one another and hence form the common complexity in clearly quantifying flow through them [13], [14]. To overcome the challenge of fracture complexity, research has been conducted on other complex fracture geometries based on evidence from images of micro-seismic mapping and outcrops from typical shale reservoirs. Through micro-seismic mapping, dendritic-like fractures have been observed [15], [16]. Since that observation, most studies have considered analytical models to study the productivity of shale reservoirs with such dendritic-like fractures [15]-[18]. These studies have a major limitation of not applying to shale reservoirs with micro-pore flow mechanisms. Besides, the studies did not consider complex flow mechanisms and efficient transfer of gas from the matrix to the fracture to the production well. At the pore scale, the shale matrix has a pore width that ranges from a few to several hundred nanometers [19]-[22]. The mechanisms of gas flow in shale matrix are different due to the nanoscale nature and complex fracture networks of shales [23]-[25]. The common flow mechanisms of gas in shales are continuum flow, slip flow, transition flow, and free molecular flow [26]-[32]. Previous studies have used the Navier-stokes equations with slip boundary to represent gas flow during the slip flow regime [33]. According to Tian et al. 2021 [5], gas desorbs from the pore surface of the matrix and then flows to the hydraulic fractures (HFs) through the connected natural fractures (NFs). Thus, a comprehensive analysis of the multiscale shale reservoir with all the flow mechanisms and fracture networks is important for an accurate evaluation of gas production.

Quantifying gas flow in shale reservoirs with evident dendritic-like fractures is still a challenge of research and a single constitutive equation which previous studies like [5], and [6] have used, cannot accurately account for the flow characteristics in shale reservoirs. Different gas flow mechanisms have been used to overcome the challenges caused by single constitutive equations [20], [25], [34]-[40]. [41] and [42] coupled slip flow, bulk diffusion, Knudsen diffusion, and surface diffusion analytically using weighted coefficients to describe gas flow in shale matrix. However, this model ignored flow in the fracture network, and like previous studies on shale reservoirs noted [43]-[51], flow in matrix-fracture is critical for efficient Analysis of overall gas flow. Various models including dual-continuum models, multiple continuum models, and discrete fracture models have been introduced to capture flow within the matrix and fracture [50]-[53]. Although these models have received an enormous application in quantifying flow in matrix and fracture, they still have inherent challenges. The first challenge is computational cost since numerous hydraulic fractures would cost too much CPU time for a single run. Also, the assumptions that fractures are continuous in the continuum model and the characteristics of individual fractures in the discrete fracture model, greatly hinder their application, especially for flow to the production well [50], [54].

Wu et al. 2014 [51] used a hybrid model to capture different scales of fractures while Zhang et al. 2016 [55] used a combination of dual-porosity dual-permeability continuum model and discrete fracture model to represent the gas flow. Xia et al. 2017 [56] further considered the SRV and volume outside the SRV to capture gas pressure distribution. Geng et al. 2018 [57] used the continuum model and discrete fracture model to describe the gas flow. Geng et al. 2018 [57] ignored the effect of stress sensitivity in their model. Although these studies have contributed to solving the challenge of the flow of gas in the matrix and fractured reservoirs, it is still challenging to accurately capture the gas flow in reservoirs with many dendritic-like fractures and perforation clusters. In this regard, Fan et al. 2015 [58] introduced a coupled gas flow and deformation model with the effect of pore compressibility and

non-Darcy. In the model of Fan et al. 2015 [58], surface diffusion which is a common flow phenomenon in shale reservoirs is ignored. This, therefore, doesn't make the model more reliable. The discrete fracture model (DFM) has made tremendous achievements in the simulation of fracture since the model explicitly describes a real fracture network. Previous studies that have applied DFM have considered flow around fracture networks and coupled it with geomechanics to capture the effect of stress on the gas flow [48], [59]-[62]. For example, Tian et al. 2021 [5] used a fractal approach for a dual-continuum model and incorporated the effective-stress-dependent permeability. This study demonstrated the connection between the pre-existing natural fractures and the induced primary and secondary hydraulic fractures. However, the study of Tian et al. 2021 [5] only considered a quarter of the entire reservoir and did not consider the gas transfer mechanism from the matrix to the fracture system. During the process of hydraulic fracturing, both primary and secondary HFs are created and should be considered in a numerical simulation model to effectively capture interdependence between fracture and matrix [63]-[66]. Therefore, a model that considers fractal-based dendritic-like HFs with an inherent gas transfer, mechanical, and flow mechanisms need to be established.

In this study, we establish a model with fractal-based dendritic-like HFs connected to pre-existing natural fractures and shale matrix. Different from previous studies, we consider the entire shale reservoir and incorporate gas transfer mechanisms. We couple the different gas flow mechanisms into a single apparent permeability equation for the matrix and fracture network and incorporate it into the Vermeulen gas transfer model and stress sensitivity. We validate the model by matching it with field data from the Barnett shale reservoirs to predict gas production of the proposed model against field data in the long term (1600 days) respectively. This study provides useful information in understanding gas flow and deformation in shale reservoirs with complex dendritic-like fractures.

2. Conceptual model

Gas flow in subsurface shale reservoirs is from the matrix where it is stored through the NFs interconnected with the HFs (primary and secondary HFs) to the production well. This trend of the flow of gas across various scales establishes complexity in accurately determining the contribution of each domain to gas flow and production during numerical simulation. We overcome this challenge by considering fractal-based dendritic-like HFs interconnected with the pre-existing NFs and establish a mechanism of gas transfer from matrix>natural fractures>secondary HFs>primary HFs>production well using the Vermeulen transient gas transfer model. We capture the actual field condition of the tendency of secondary HFs to form during the stimulation process and account for shale deformation as a result of prolonged production as shown in Fig. 1. The primary HFs are intersecting the horizontal well at 90° while secondary HFs propagate from the PFs and bifurcate at 80° and extend to connect with the NFs that are randomly oriented within the matrix domain. A combination of the primary HFs, secondary HFs, and activated NFs constitute the SRV. Activated NFs refer to those NFs that are in direct contact with either the primary HFs or the secondary HFs. Previous studies have defined SRV as both the induced surface of hydraulic fractures and the corresponding set of activated natural fractures in shale reservoirs [19]. The drainage area of the SRV is of particular importance because it describes pressure distribution around the fracture network and pressure drop in the horizontal well. Compared with the unstimulated reservoir volume (USRV), the permeability of the SRV is dynamic and changes with various impacts including flow mechanisms and stress changes in the reservoir while the permeability of the USRV is almost negligible due to the extremely low permeability of the shale reservoirs [67]-[69].

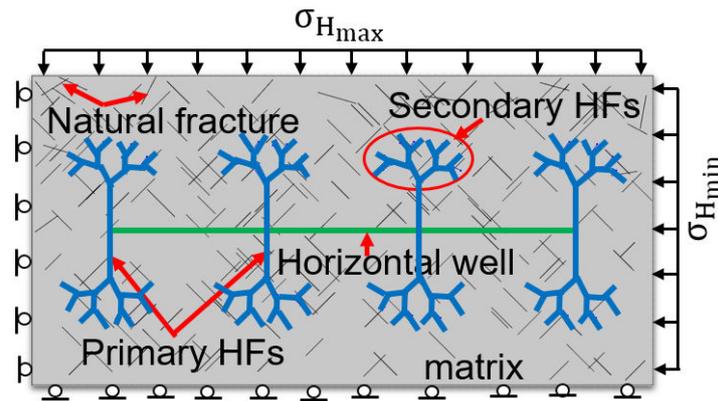


Fig. 1. Schematic representation of the conceptual model for the fractal-based dendritic-like HF, flow, and shale deformation.

To account for matrix shrinkage due to gas flow and production, the top and right boundaries are loaded with maximum and minimum stress values of 40MPa and 37MPa respectively while roller loads are applied to the left and bottom boundaries. Fig. 1 illustrates a horizontal well that is intersected by dendritic-like hydraulic fractures that create secondary fractures connecting with the existing natural fractures and shale matrix. Since gas production involves complex inter-relationships between flow and deformation, we establish a systematic coupled relationship between the latter two. In Fig. 2, we demonstrate this relationship in which the pressure depletion and changes in effective stress impact flow by altering the apparent permeability since it is highly dependent on pressure. In addition, a decrease in pore pressure increases effective stress that eventually leads to compaction of fracture network due to reduced aperture and permeability. Hence, the coupling amongst the flow and deformation is either pressure-dependent or effective stress-dependent and is implemented into a finite element method (FEM)-based partial differential solver considering the following assumptions:

1. The geometry of dendritic-like fractures is such that the secondary HF propagate from the primary HF and bifurcate at 80° .
2. Both fracture length and aperture follow the fractal scaling law and the branching ratio used is three. The NFs and HF are modeled as one-dimensional elements and form separate continua in space.
3. Shale is a triple poroelastic continuum (matrix, natural fracture, and hydraulic fracture). The organic matrix is similar to the inorganic matrix and constitutes a single matrix while the fracture system is divided into hydraulic fractures (primary and secondary) and natural fractures.
4. Gas flow is from matrix to natural fracture to secondary HF to primary HF and the production well. The fracture network (primary HF, secondary HF, and natural fractures) is embedded in the matrix.
5. Only single-phase (methane) flow is considered and the flow is isothermal, incompressible, and only in a single layer.
6. The effect of gravity is ignored

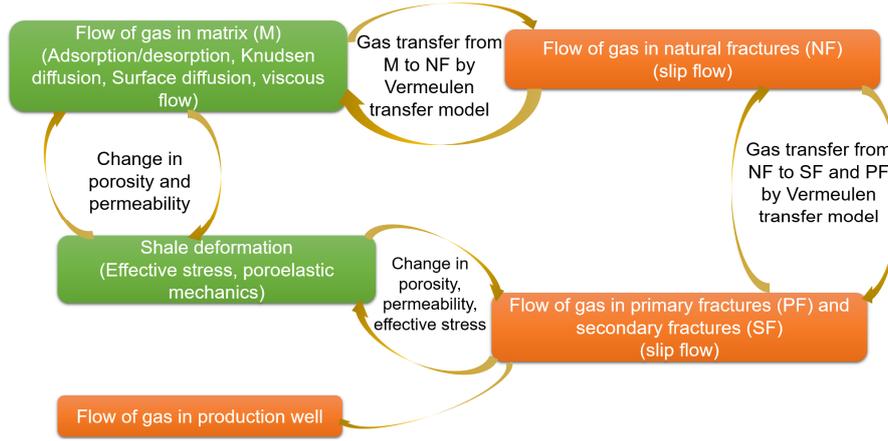


Fig. 2. Cross-coupling relationship between different fields during shale gas flow and production.

3. Governing mathematical equations

We establish a fully coupled mathematical model consisting of shale deformation, gas transfer, and gas migration mechanisms. The theory of poroelasticity proposed by Detournay and Cheng, 1993 [70] is used to establish the shale deformation mechanism based on effective stress.

3.1 Governing equation of shale deformation

We consider a homogeneous, isotropic, and triple-continuum model and hence the strain induced by stress and gas adsorption is paramount. The constitutive equation for shale deformation with matrix and fracture domains is[71]-[73]:

$$\varepsilon_{ij} = \frac{1}{2G}\sigma_{ij} - \left(\frac{1}{6G} - \frac{1}{9K}\right)\sigma_{kk}\delta_{ij} + \frac{\beta p_m}{3K}\delta_{ij} + \frac{\gamma p_{PF}}{3K}\delta_{ij} + \frac{\omega p_{NF}}{3K}\delta_{ij} + \frac{\varepsilon_s}{3}\delta_{ij} \quad (1)$$

where ε_{ij} is the component for total strain tensor; G is the shear modulus of shale and is given by $G = \frac{E}{2(1+\nu_{poi})}$; E is the young's modulus; ν_{poi} is the poison's ratio; σ_{ij} is the total stress tensor; K is the bulk modulus of shale and is given by $K = \frac{E}{3(1-2\nu_{poi})}$; β , γ , and ω are the Biot coefficients of the matrix, primary fracture, and secondary/natural fractures, respectively, and are given by $\beta = 1 - \frac{K}{K_{sh}}$, $\gamma = 1 - \frac{K}{K_{PF}}$, $\omega = 1 - \frac{K}{K_{NF}}$, $K_{PF} = K_{NF} = aK_n$; K_n is the modified stiffness of the fracture; K_{sh} is the bulk modulus of shale grains; p_m , p_{PF} and p_{NF} are the pressures of gas in the matrix, primary/secondary fractures, and natural fractures respectively; δ_{ij} is the Kronecker delta; ε_s is the sorption-induced volumetric strain and is[74]:

$$\varepsilon_s = \varepsilon_L \frac{p_m}{(p_m + p_L)} \quad (2)$$

where ε_L is the Langmuir volumetric strain where the pore pressure is infinite; p_L is the constant for Langmuir pressure in MPa at which the pore pressure is one-half of the Langmuir volumetric strain ($0.5\varepsilon_L$). Finally, the governing equation of shale deformation is obtained by combining the equilibrium equation $\sigma_{ij,j} + f_i = 0$ and Cauchy's equation $\varepsilon_{ij} = \frac{(u_{i,j} + u_{j,i})}{2}$:

$$Gu_{i,kk} + \frac{G}{(1 - 2\nu_{poi})}u_{K,KI} - \beta p_{m,i} - \gamma p_{PF,i} - \gamma p_{NF,i} - K\varepsilon_{s,i} + f_i = 0 \quad (3)$$

where u is the displacement under effective stress, f_i is the component of body force.

3.2 Gas migration in the matrix

Shale reservoirs have different pore scales that create complexity in the flow of gas and the Knudsen number is usually applied to describe the migration phenomena [35], [75]-[79]. The pore-scale of the shale matrix is usually in nanometers and multiple flow mechanisms including slip, Knudsen diffusion, viscous, and surface diffusion occur [21], [80]. We apply the Vermeulen transfer equation to account for gas transfer and interaction between the matrix and fracture. The continuity equation of the matrix is:

$$\frac{\partial U_{M_{kn}}}{\partial t} = \nabla U_{M_{kn}} + \nabla U_{M_{vis}} - J_{M_{NF}} \quad (4)$$

where, $U_{M_{kn}}$ is the term for the Knudsen diffusion in the shale matrix; $U_{M_{vis}}$ is the term for viscous flow in the matrix; $J_{M_{NF}}$ is the term for gas transfer mechanism from matrix to the existing natural fractures:

$$U_{M_{kn}} = -\varepsilon_M \varphi_M D_M \nabla m_M \quad (5)$$

where ε_M is the portion in the pore volume of the shale matrix; φ_M is the porosity of the matrix. The tortuosity-corrected Knudsen diffusivity of the matrix (D_M) is:

$$D_M = 5.33 \varphi_M^{\frac{-1}{3}} \sqrt{\frac{k_{M_0} RT}{\pi M}} \quad (6)$$

where R is the ideal gas constant, 8.314 J/K/mol, M is the molecular weight of natural gas, T is the temperature in K. The evolution of porosity in the matrix domain under the action of effective stress is determined using the equation of dynamic porosity that is pressure- and stress-dependent [74]:

$$\varphi_M = \varphi_{M_0} \exp(-c_m [\bar{\sigma} - \bar{\sigma}_0 - (p_m - p_{m0})]) \quad (7)$$

where φ_{M_0} is the initial porosity of the matrix, c_m is the compressibility of the matrix in Pa^{-1} , $\bar{\sigma}$ and $\bar{\sigma}_0$ are the mean total stresses at current and initial states, respectively, p_{m0} is the initial gas pressure in the matrix domain.

The viscous flow term (U_{M_vis}) is:

$$U_{M_vis} = -m_M \frac{k_{M_o}}{\mu} \nabla p_m \quad (8)$$

where m_M are the moles of free gas in the matrix in mol/m³; k_{M_o} is the initial permeability of the matrix in m²; μ is the viscosity of methane gas in Pa.s; and p_M is the pressure in the matrix in MPa.

The viscosity of methane (μ) is [81], [82]:

$$\begin{aligned} \mu &= 10^{-7} n e^{l(0.001\rho_m)^s} \\ n &= \frac{(9.379 + 0.01607M)(1.8T)^{1.5}}{(209.2 + 19.26M + 1.8T)} \\ l &= 3.448 + \left(\frac{986.4}{1.8T}\right) + 0.01M \\ s &= 2.447 - 0.2224l \end{aligned} \quad (9)$$

where ρ_m is the density of methane gas and is:

$$\rho_m = \frac{pM}{ZRT} \quad (10)$$

where p is the pore pressure in the shale matrix in MPa; Z is the compressibility factor of methane gas.

According to previous experimental and analytical studies [19], [83], Z is calculated using either the Peng-Robinson equation of state (PR-EOS) or the equation of explicit empirical. We adopt the empirical equation of [84], since we considered a single gas component with respective pseudo-temperature and pseudo-pressure as:

$$\begin{aligned} Z &= (0.702e^{-2.5T_{pred}})p_{pred}^2 - (5.524e^{-2.5T_{pred}})p_{pred} \\ &+ (0.044T_{pred}^2 - 0.164T_{pred} + 1.15) \\ p_{pred} &= \frac{p}{p_{crt}} \\ T_{pred} &= \frac{T}{T_{crt}} \end{aligned} \quad (11)$$

where p_{pred} and T_{pred} are the reduced-pressure and reduced-temperature, dimensionless; p_{crt} and T_{crt} are the critical pressure in MPa, and critical temperature of methane gas in K, respectively.

The Vermeulen gas transfer term [85], $J_{M_{NF}}$, for gas transfer from the matrix to the natural fractures is:

$$(12)$$

$$J_{M_{NF}} = \frac{ZRTm_M k_M \sigma_{M_{NF}} (m_M - m_{NF})}{\mu}$$

where k_M is the dynamic apparent permeability of the shale matrix before coupling with effective stress in m^2 ; $\sigma_{M_{NF}}$ is the Vermeulen shape factor for transient gas flow in l/m^2 [85]; m_{SF} is the moles of gas in the secondary and existing natural fractures in mol/m^3 . $\sigma_{M_{NF}}$ is:

$$\sigma_{M_{NF}} = 4 \left(\frac{1}{(V_X)^2} + \frac{1}{(V_Y)^2} \right) \frac{2m_0 - (m_M + m_{NF})}{2(m_0 - m_M)} \quad (13)$$

where, V_X and V_Y represent the spacing between the fractures in the x and y directions; m_0 are the moles of gas at its initial state; $m_0 = \frac{p_0}{ZRT}$; p_0 is the initial reservoir pressure in MPa.

The dynamic apparent permeability of the matrix without considering effective stress is obtained by coupling all the flow mechanisms in the matrix as:

$$k_M = k_{M_0} \left(1 + \frac{\varphi_M D_M \mu}{(m_M ZRT k_{M_0})} \right) \quad (14)$$

The equation of permeability evolution due to change in porosity for shale reservoirs is[72]:

$$k_{M_c} = k_M \left(\frac{\varphi_M}{\varphi_{M_0}} \right)^3 \quad (15)$$

where k_{M_c} is the coupled permeability equation as a result of changes in matrix porosity.

The overall governing equation of gas flow in the matrix domain is:

$$\varphi_M \frac{\partial m_M}{\partial t} - \nabla \left\{ \left[m_M ZRT \frac{k_{M_0}}{\mu} + \varphi_M D_M \right] \nabla m_m \right\} = J_{M_{NF}} \quad (16)$$

$$\nabla = \frac{\partial}{\partial x}$$

3.3 Gas migration in the fracture system

We consider the existing natural fractures, secondary hydraulic fractures and primary hydraulic fractures to formulate the governing equation of permeability and couple the equation with effective stress based on slip and viscous flow. Slip-corrected permeability on a fracture network is paramount during shale gas performance evaluation [86], [87]. The Vermeulen transfer model is used both in the transfer of gas from the matrix to existing natural fractures and secondary fractures and transfer of gas from the existing natural fractures and secondary hydraulic fractures to the primary hydraulic fractures. For the fractal-based dendritic-like HF in this study, we use a branching ratio of three, hence $l_y = 3l_{y-1}$ and $d_y = 3d_{y-1}$ as demonstrated in Fig. 3. First, we consider the transfer of gas from the shale matrix to the natural fractures as:

$$\nabla \left(\frac{m_{NF} ZRT K_{NF}}{\mu} \nabla m_{NF} \right) + J_{M_{NF}} - J_{NF_{PF}} = \frac{\partial (\varphi_{NF} m_{NF})}{\partial t} \quad (17)$$

where m_{NF} are the moles of free gas in the natural fractures in mol/m³; K_{NF} is the apparent permeability of the natural fractures in m²; $J_{NF_{PF}}$ is the Vermeleun transfer term from natural fractures to the primary/secondary HF's in mol/(m³s); φ_{NF} is the porosity of the natural fractures. $J_{SF_{PF}}$ is:

$$J_{NF_{PF}} = \frac{ZRTm_{NF}K_{NF}\sigma_{M_{PF}}(m_{NF} - m_{PF})}{\mu} \quad (18)$$

where m_{PF} are the moles of free gas in the primary hydraulic fractures in mol/m³; $\sigma_{M_{PF}}$ is the transient shape factor for flow to the primary fractures in 1/m²:

$$\sigma_{M_{PF}} = 4 \left(\frac{1}{(V_X)^2} + \frac{1}{(V_Y)^2} \right) \frac{2m_0 - (m_{NF} + m_{PF})}{2(m_0 - m_{NF})} \quad (19)$$

To capture the slipping tendency of gas flow in the fracture network, we use the Klinkenberg effect in the apparent permeability of the fracture as:

$$K_{NF} = K_{NF_0} \left(1 + \frac{b_{NF}}{p} \right) \quad (20)$$

where K_{NF_0} is the initial permeability of the natural fractures; b_{NF} is the slippage term and is [88]:

$$b_{NF} = \left(\frac{D_{NF}\mu}{K_{NF_0}} \right) \quad (21)$$

$$D_{NF} = \frac{4K_{NF_0}}{2.8284 \sqrt{\frac{K_{NF_0}}{\varphi_{NF}}}} \sqrt{\left(\frac{\pi RT}{2M} \right)}$$

where D_{NF} is the coefficient term for Knudsen diffusion.

During the process of gas production, the permeability of the fracture network decreases with increasing effective stress. The coupled evolution of fracture permeability in the natural fractures is [5], [89], [90]:

$$K_{NF_c} = K_{NF} \exp(-c_{nf}(p - p_{NF})) \quad (22)$$

Where K_{NF_c} is the coupled permeability equation of the natural fracture due to changes in stress and porosity and c_{nf} is the compressibility of the natural fractures.

For transfer from the primary hydraulic fractures to the production well, we account for effective gas transfer and flow as:

$$\nabla \left(\frac{m_{PF}ZRTK_{PF}}{\mu} \nabla m_{PF} \right) + J_{NF_{PF}} - Q_f = \frac{\partial(\varphi_{PF}m_{PF})}{\partial t} \quad (23)$$

where K_{PF} is the apparent permeability of the primary hydraulic fractures in m². The tendency of slip flow in the primary and secondary HF's is:

$$K_{PF} = K_{PF_0} \left(1 + \frac{b_{PF}}{p} \right) \quad (24)$$

where K_{PF_0} is the initial permeability of the primary hydraulic fractures; b_{PF} is the slippage term and is analogous to Eq. (21). We obtain the equation of coupled apparent permeability under the influence of effective stress in the primary HF as:

$$K_{PF_c} = K_{PF} \exp \left(-c_{pf}(p - p_{PF}) \right) \quad (25)$$

where K_{PF_c} is the coupled equation of the primary/secondary HFs due to changes in stress and pressure, c_{pf} is the compressibility of the primary/secondary HFs.

From Eq. (23), Q_f is the gas flow term to the production well and is [91]:

$$Q_f = \left(\frac{K_{PF} m_{PF} ZRT}{\mu} \right) \left(\frac{\theta_{ang}}{\ln(r_e - r_w)} \right) (m_{PF} - m_W) \quad (26)$$

where θ_{ang} is the location of the well; m_W is the moles of free gas in the well in mol/m³; $m_W = \frac{p_W}{ZRT}$; p_W is the bottom-hole pressure in the production well; r_e and r_w are the drainage and well radii respectively; r_e is [91]:

$$r_e = \left\{ 0.14 \sqrt{[(\Delta V_X)^2 + (\Delta V_Y)^2]} \text{ for } K_x = K_y \right\} \quad (27)$$

where ΔV_X and ΔV_Y are the sizes of the reservoir block grids in the x and y directions; K_x and K_y are the permeability values in x and y directions [76].

Finally, we incorporate the initial and boundary conditions to aid the convergence of the proposed model. Initial conditions are derived based on pressure, moles of free gas, and time as:

$$p_M(x, y, t)|_{t=0} = p_{NF}(x, y, t)|_{t=0} = p_{PF}(x, y, t)|_{t=0} = p_0 \quad (28)$$

where p_M , p_{NF} , p_{PF} and p_0 are the pressures in the matrix, natural fractures, primary/secondary HFs, and initial pressure respectively:

$$m_M(x, y, t)|_{t=0} = m_{NF}(x, y, t)|_{t=0} = m_{PF}(x, y, t)|_{t=0} = \frac{p_0}{ZR_{meth}T} \quad (29)$$

For the inner boundary conditions, the following boundary conditions in terms of pressure are used:

$$p_{NF}(x, y, t)|_{\omega_{inp}} = p_{PF}(x, y, t)|_{\omega_{inp}} = p_W \quad (30)$$

where ω_{inp} is the condition for the inner surface of the fracture system; p_W is the bottom-hole pressure in MPa.

The inner boundary conditions in terms of moles of free gas are:

$$m_{NF}(x, y, t)|_{\omega_{inp}} = m_{PF}(x, y, t)|_{\omega_{inp}} = \frac{c}{ZRT} \quad (31)$$

The outer boundary conditions in terms of pressure for the matrix, secondary/natural fractures, and primary hydraulic fractures are obtained as derivatives of space and time as:

$$\frac{\partial p_M}{\partial t}|_{\omega_{outb}} = \frac{\partial p_{NF}}{\partial t}|_{\omega_{outb}} = \frac{\partial p_{PF}}{\partial t}|_{\omega_{outb}} = 0 \quad (32)$$

where ω_{outb} is the outer boundary term and the summation of the inner boundary term and outer boundary term is equal to the unit ($\omega_{outb} + \omega_{inp} = 1$).

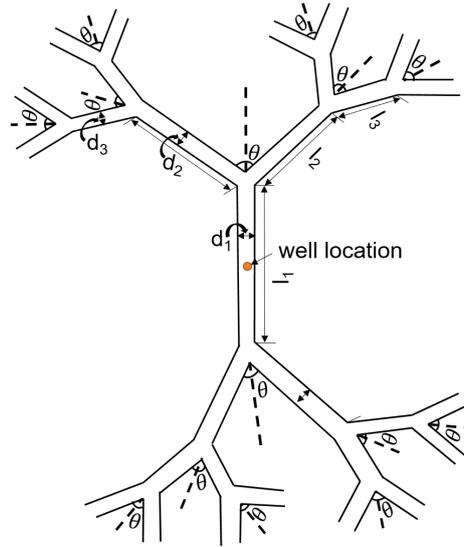


Fig. 3. Schematic demonstration of a single multi-level branched fractal-based dendritic-like HF

3. Model verification

The governing equations in section 2 demonstrate a multi-scale heterogeneous system with gas flow and shale deformation coupled together using the PDE solver of Comsol. The fractal-based dendritic-like HF, NF, and matrix are treated as a triple-continuum media with the fracture system (HF and NF) represented as 1D conduit elements. We verify the current model using two different cases namely: First, we illustrate the superiority of the current model by comparing it with conventional bi-wing fracture using an ideal reservoir with small dimensions (40m x 20m). Then we further prove the performance of the proposed model by comparing production with the field data from the Barnett shale reservoir. The simulation parameters are obtained from existing literature and are shown in Table 1 [57], [92].

3.1 Case1: Verification against conventional bi-wing HF

The coupled flow and mechanical models used for the verification of gas production are illustrated in Fig. 4. The model dimensions are 40 m by 20 m in length and width respectively and the thickness is 10 m. We apply maximum horizontal stress of 40 MPa and minimum horizontal stress of 37 MPa on the top-and right-side boundaries, respectively, and roller constraints are applied on the left and bottom sides respectively while the other boundaries are set as no flow zones. Parameters used in the verification process are listed in Table 1. The cases considered in the verification process are: (1) the base case having NFs, primary and secondary HFs (multi-fracture geometry. Fracture propagation into

a complex network), (2) conventional bi-wing fractures without induced secondary HFs (single fracture geometry. Fracture propagation in the direction of fracture half-length). From Fig. 4, the production from the two cases indicates that the current model that contains both natural fractures, primary HFs, and secondary HFs performs better than conventional bi-wing primary HF that contains planar HFs without secondary HFs. This is because when secondary HFs are created, the area of contact with the existing natural fractures (NFs) that are both near and far the HFs increases and hence expands gas flow paths from matrix to fracture hence improving production. Whereas, in the case where there is no secondary HF (conventional bi-wing fractures), the area of contact with existing NFs is limited to only those NFs in the neighborhood of the primary HF and hence the limited flow of gas that eventually hinders production.

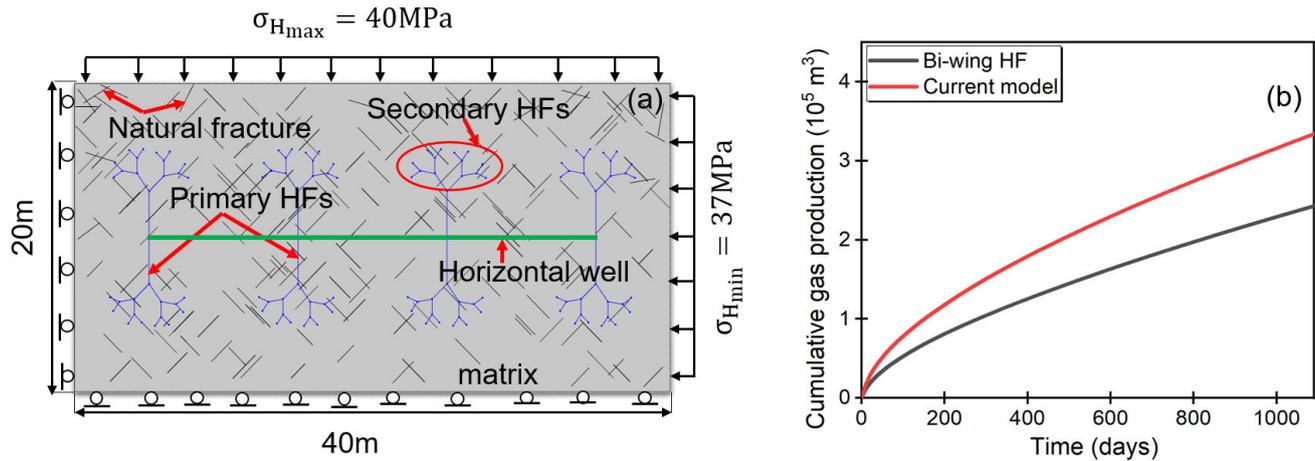


Fig. 4. Numerical simulation case and production evaluation: (a) base case model with fracture network (NFs and HFs) and mechanical deformation; (b) comparison of production performance between the bi-wing hydraulic fracture and the current model (dendritic-like hydraulic fractures)

Table 1

Reservoir parameters used for verification of the current model

Parameter	Current model	Field model	Unit
Dimensions	40 x 20 x 10	550 x 145 x 90	m
Initial reservoir pressure, p_i	20.3	20.34	MPa
Poisson's ratio, ν_{poi}	0.25	0.25	
Young's modulus, E	26	26	GPa
Bulk modulus of shale, K	15	15	GPa
Biot coefficient of matrix, β	0.054	0.054	
Langmuir pressure, p_L	3×10^6	4.48×10^6	Pa
Langmuir volume, v_L	2.5×10^{-3}	2.72×10^{-3}	m^2/kg
Well pressure, p_w	10.3	3.69	MPa
Temperature, T	352	352	K
Fractal bifurcation angle	80	80	

Compressibility of NFs, c_{nf}	3×10^{-9}	1×10^{-8}	Pa^{-1}
Compressibility of HF, c_{pf}	2×10^{-9}	5×10^{-9}	Pa^{-1}
Initial NF permeability, K_{NF_0}	30	1.5	mD
NF aperture	0.0005	0.0005	m
Number of primary HF	4	28	
Bifurcating ratio	3	3	
HF spacing	10	30.5	m
Surface diffusion coefficient	1×10^{-8}	1×10^{-8}	m^2/s
Viscosity, μ	Dynamically computed		Pa.s

3.2 Case2: Verification against field data from Barnett shale

Shale reservoirs have existing NFs and have been investigated in previous studies [93]-[95]. Barnett shale reservoir is located in the Bend Arch-Fort Worth basin in Texas, USA, and consists of sedimentary rocks that date back from the Mississippian period between 323-354 million years ago [96]. Fan and Ettehadtavakkol, 2017 [97] upscaled the microseismic data and observed that the induced fractures form a dendritic-like shape. According to Ruppert et al. 2013 [98], the pore size of the Barnett matrix constitutes a fractal theorem alongside the induced HF. Hence, in this study, we verify the current model against production data from the Barnett shale reservoir [92]. The parameters used in the simulation process are listed in Table 1 in subsection 3.1. From Fig. 5, the gas production rates are compared with field data and previous studies. The decline in gas production rates of the current model varies from $2.5 \times 10^5 \text{ m}^3/\text{day}$ to $0.5 \times 10^5 \text{ m}^3/\text{day}$ during the total production forecast of 1600 days and matches well with field data.

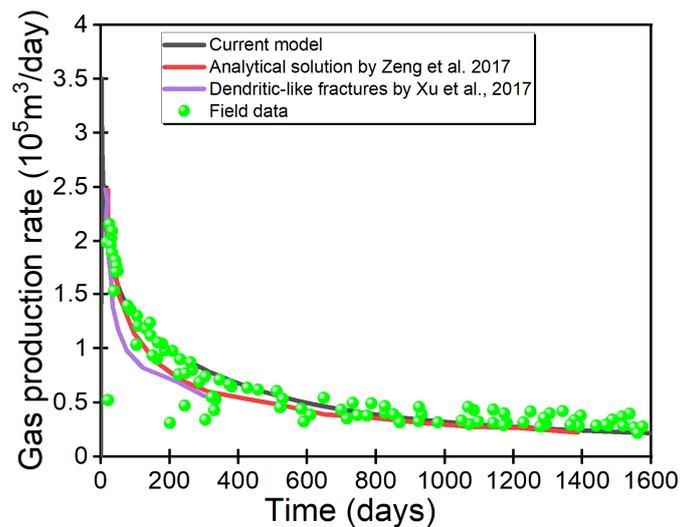


Fig. 5. Comparison of simulation results with field data, Analytical solution, and previous studies on fractal-based dendritic-like hydraulic fractures in the Barnett Shale.

4. Sensitivity analysis of influencing parameters

We analyze the impacts of different scales on permeability and porosity evolution during gas production. We enlarge the base case model in subsection 3.1 by x10 and upscale it to fit field-scale conditions with dimensions of 400 m x 200 m x 100 m in length, width, and thickness respectively as shown in Fig. 6. The boundary conditions remain the same as those in the base case model and the fracture network consists of the NFs and HF (primary and secondary HFs). The total number of primary HFs is seven and the bifurcation angle is 80° with an in-between primary HF spacing of 50 m. The parameters used in the simulation of the upscaled model are listed in Table 2 and other parameters are similar to the parameters used in the base case model. For effective sensitivity analysis, we divide the parameters into effective stress (stress sensitivity coefficient) and fracture parameters (number of branching secondary HFs, fracture bifurcating angle).

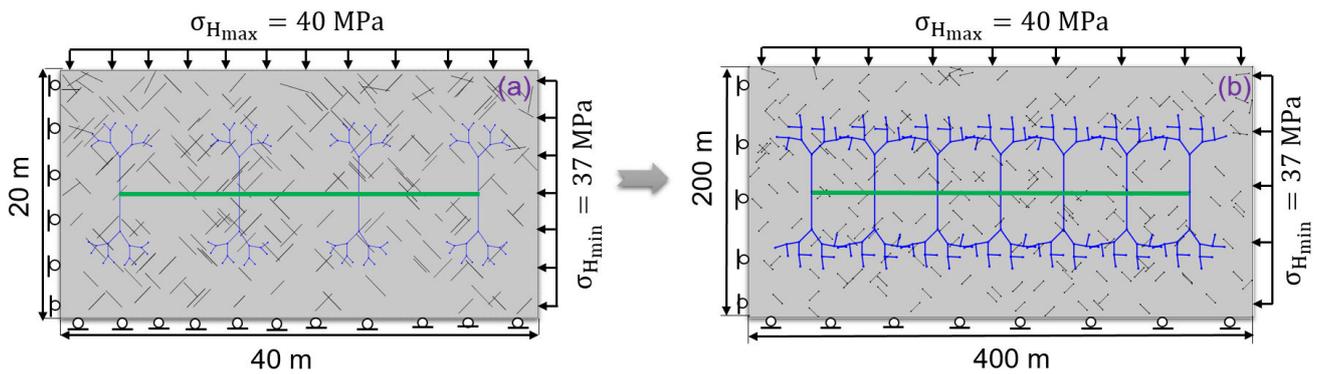


Fig. 6. Schematic representation of the physical geometry of the upscaled field case model: (a) base case model; (b) field scale model

Table 2

Parameters used in the sensitivity analysis model

Parameter	Value	Unit
Matrix compressibility, c_m	4.5×10^{-10}	Pa^{-1}
Initial NF permeability, K_{NF_0}	1.5	mD
NF width	0.0005	m
Number of NFs	100-200	
HF width	0.003	m
Number of primary HFs	14	
Bifurcating angle	$40-100^{\circ}$	Degrees
Branching ratio	3	
HF spacing	50	m
Initial HF permeability, K_{PF_0}	100	mD
Half-length of HF	25	m

4.1 Stress sensitivity of shale reservoir

During shale gas production, the rock is under considerable stress that eventually leads to matrix shrinkage [99], [100]. Considering the impact of effective stress is paramount for efficient production evaluation. In this section, we analyze the impact of the stress sensitivity coefficient on gas production for a forecast period of 30 years. Values of stress sensitivity coefficient considered are 0.02 MPa^{-1} , 0.04 MPa^{-1} , 0.06 MPa^{-1} and 0.08 MPa^{-1} as shown in Fig. 7. When the stress sensitivity coefficient increases, the cumulative gas production drastically reduces. This is because the rock is under compression which adequately hinders the smooth flow of gas and hence negatively affects gas production. The lower value of stress sensitivity coefficient needs to be selected if higher production is to be achieved.

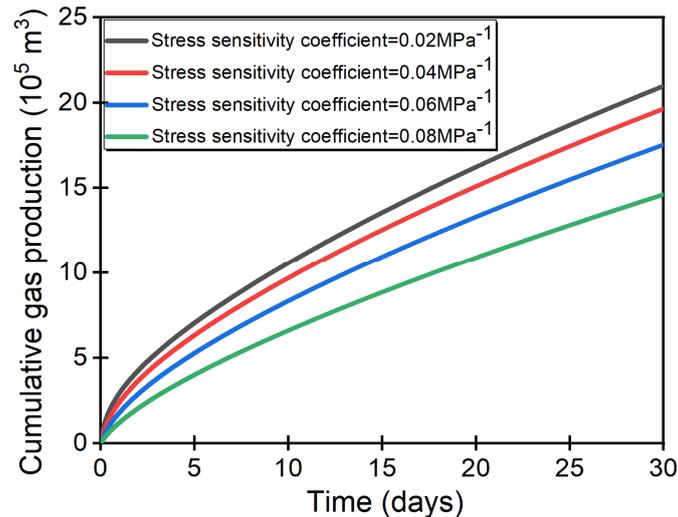


Fig. 7. Influence of stress sensitivity coefficient on cumulative gas production

4.2 Influence of fracture parameters on gas production

We deeply analyze the influence of fracture parameters including HF bifurcating angle and HF geometry (branch). For fracture bifurcating angle, to properly analyze the influence of the bifurcating angle on gas pressure evolution, distribution and gas production, we extract the portion of the branching secondary HFs and use them in analysis considering different cases having varying angles including 0° , 30° , 60° , and 120° for case 1, case 2, case 3, and case 4 respectively. These fracture angles demonstrate the typical orientation of secondary HFs in field conditions and have a huge influence on gas pressure distribution and production as shown in Fig. 8 (a-d). From Fig. 8, the gas pressure distribution is unique for different fracture angles. The pressure distribution and contact area of the HF with neighboring natural fractures and matrix is minimal in case 1 and is large enough in case 4. When the fracture angle is increased, the secondary HFs extend further to contact with more natural fractures than when the fracture angle is small. Cumulative gas production increases with an increase in fracture angle. For example, from Fig. 8 (e), when the fracture angle is small, cumulative production is low as compared to when the fracture angle is large. However, as the fracture angle increases, a point is reached when an increase in fracture angle does not significantly increase production.

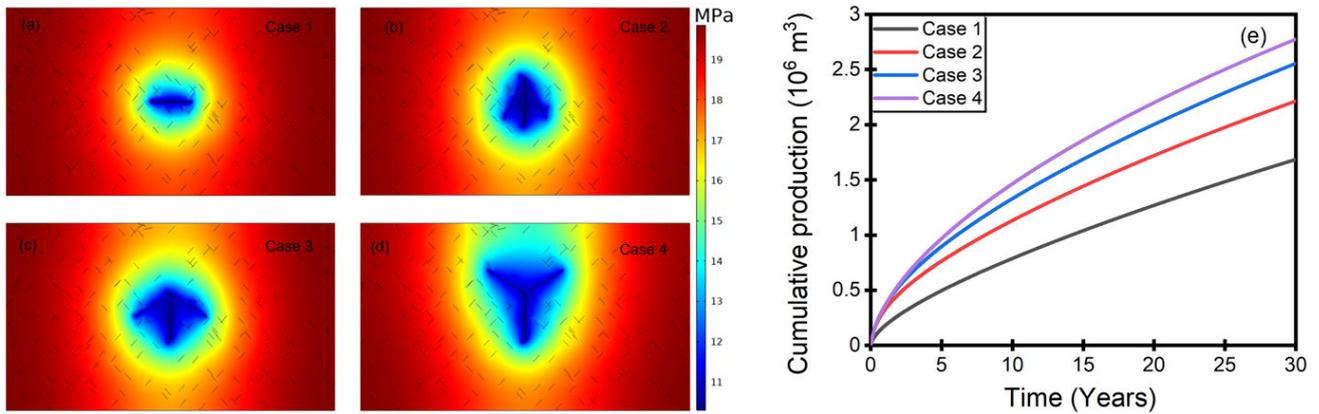


Fig. 8. Comparison of pressure evolution and cumulative production of different angles of secondary: (a) fracture angle = 0° ; (b) fracture angle = 30° ; (c) fracture angle = 60° ; (d) fracture angle = 120° ; (e) comparison of cumulative gas production for the cases considered.

We consider fracture geometry with the dendritic-like fractures and typical field conditions of the orientation of fracture networks as shown in Fig. 9. We adopt different cases having varying branching numbers ranging from 0 to 3 branches to depict the typical dendritic-like structure and analyze their performance in terms of pressure distribution. From Fig. 9 (a-d), secondary HFs have a direct influence on gas pressure distribution. For example, in Fig. 9 (a), when there are no secondary HFs, the interaction of the HFs with the NFs is limited to only fractures nearby and fractures away from the stimulated reservoir volume (SRV) are not connected. This leaves the majority of the gas unexploited since the pressure distribution is not uniform. When secondary HF is initiated as shown in Fig. 9 (b), the area of contact with the NFs increases steadily. This implies that NFs that were initially not connected are now covered with the steadily increasing pressure distribution thus increasing the flow path of the gas stored in the matrix. As more branches are created as shown in Fig. 9 (c & d), more NFs are connected and the path of gas to flow to the production well increases. As the pressure around the production well and HF drops, the pressure for the area far away from the HF is still high and hence supports production in the late days of production due to improved connectivity as a result of the increased number of branches. This is evident from the steadily increasing SRV as a result of an increasing number of secondary HF branches. This study indicates that dendritic-like secondary HFs are more important in estimating the positive contribution of SRV to gas pressure distribution.

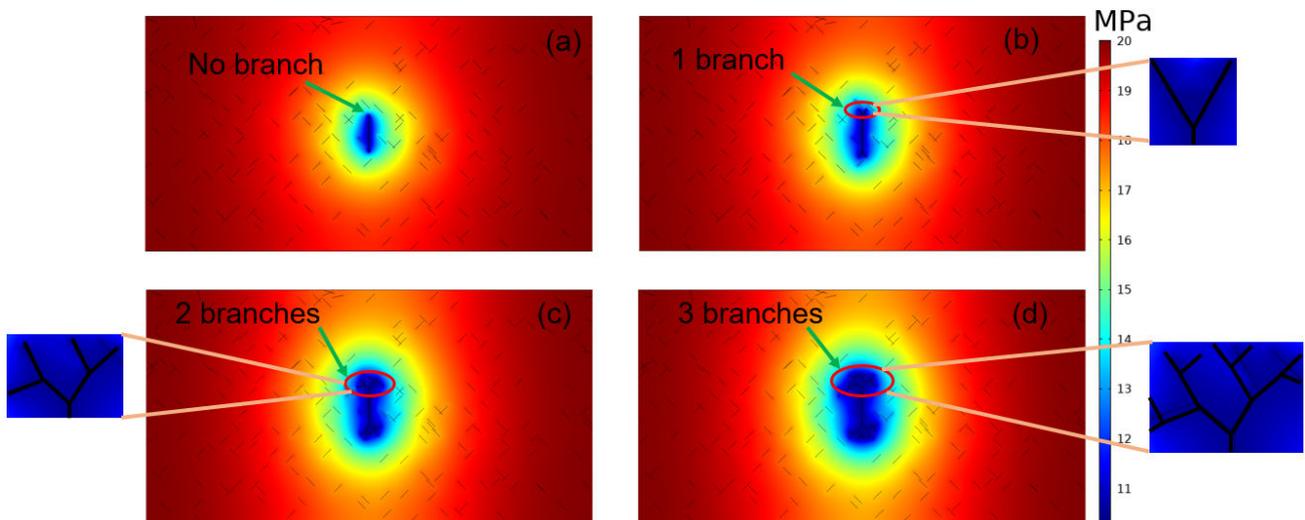


Fig. 9. Gas pressure distribution for different primary HFs with varying number of secondary HF branches: (a) primary HF without secondary HFs (conventional bi-wing HF with no branch), (b)

primary HF with a single branch of secondary HF, (c) primary HF with a double branch of secondary HF, (d) primary HF with the triple branch of secondary HF.

The more the number of fracture branches the more the contact area and improved flow path for gas, hence increased cumulative gas production as shown in Fig. 11 (a). The case with no secondary HF has lower cumulative gas production as compared to the cases with secondary HF. To explain this phenomenon, we analyze the pressure evolution in the matrix and fracture network for the four cases at the position (190 m, 100 m) as shown in Fig. 10.

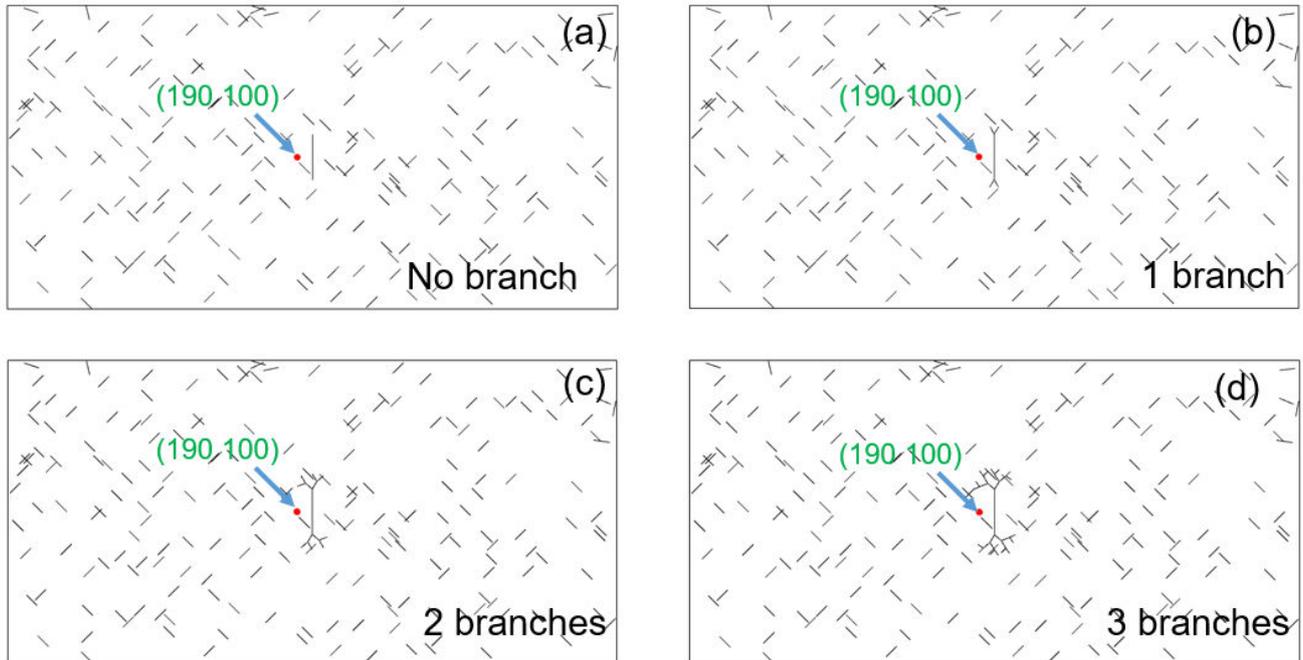


Fig. 10. Point representing pressure evolution analysis in the matrix

This point is approximately 10 m away from the production well. The reason for choosing this point is to analyze the pressure evolution due to fluid flow and production from the matrix as a result of the four cases. Fig. 11 (b) shows the pressure evolution for the cases and indicates that the pressures decline at different rates. The case with three branches has a faster pressure decline rate. This is because the permeability is improved with many fracture branches thus leading to faster pressure drops. The case with no secondary fracture branches has the lowest pressure drop because the permeability is not adequately improved. The findings from this pressure evolution analysis are consistent with the previous studies [101]. Fracture branches play a crucial role in connecting multiple NFs and that eventually attracts more gas to flow to the production well easily hence higher production.

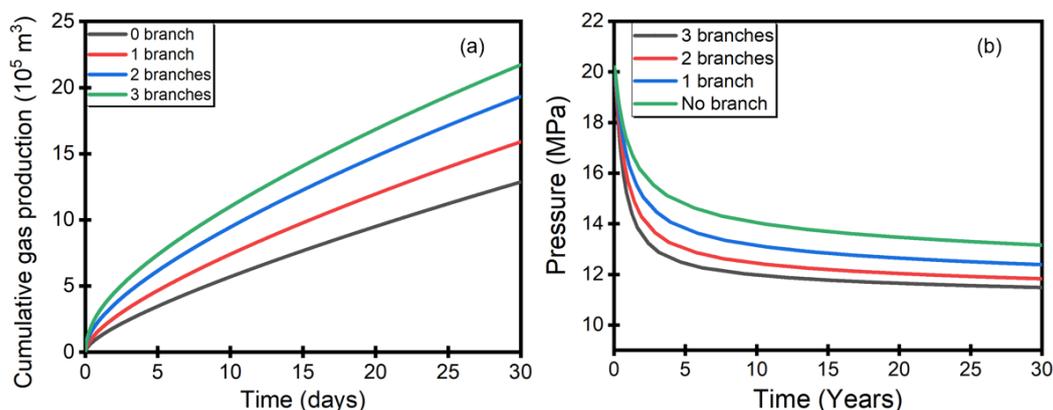


Fig. 11. Production performance evaluation: (a) comparison of cumulative gas production for the different number of fracture branches; (b) pressure evolution analysis of the three cases.

5. Conclusions

In this study, we establish a fully coupled model for analyzing complex gas transfer and flow in nanoporous shale reservoirs using the finite element method. Permeability of the matrix depends on effective stress while fracture permeability depends on pressure. Various flow mechanisms corresponding to matrix and fracture systems are considered at the microscale and macroscale respectively using dendritic-like hydraulic fractures. Validation results indicate that complex gas transfer and flow through dendritic-like fractures perform better than conventional bi-wing fractures and match well with field data. Various parameters have a significant influence on shale gas production:

- 1) When the effect of geomechanics is considered, gas production drastically reduces. This is because the rock is under considerable stress that eventually limits the flow of gas hence reducing production.
- 2) Fracture angle is paramount in shale reservoirs and is useful in increasing the contact area and hence extracting more gas from the shale matrix.
- 3) Dendritic-like fractures extend the contact area of the matrix and fracture and hence can be considered in the field application of gas production. Simulation results indicate that branched dendritic-like HFs are more reliable when transmitting gas from the matrix to the fracture system and production well than the unbranched hydraulic fractures.
- 4) The matrix stores a considerable amount of gas that flows easily to the natural fractures. From the natural fractures, the gas flows to the connected hydraulic fractures and finally to the production well. Results show that more gas is obtained when there are more branches of secondary HFs since they connect with many NFs.

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Credit author statement

Marembo Micheal: Methodology, Conceptualization, Writing, Simulation, Investigation (Prepared original draft). Silagi Wanambwa: Analysis of results, Writing, Reviewing and editing, Methodology. Theodora Twongyirwe Mondo: Supervision, Conceptualization, Methodology, Writing, Reviewing and editing, Compilation. Jacqueline Nangendo: Methodology, Reviewing and editing, Compilation, Analysis of results. Rodney Lubega: Reviewing and editing, Modification. Arnaud Regis Kamgue Lenwoue: Reviewing and editing, Analysis of results, Modification. Matamba Musungayi Georges: Reviewing and editing

Nomenclature

p_i	Initial reservoir pressure, MPa
p_w	Well pressure, MPa
ν_{poi}	Poisson's ratio
K_{NF_0}	Initial NF permeability, mD
c_m	Matrix compressibility, Pa ⁻¹
c_{nf}	Compressibility of NFs, Pa ⁻¹
c_{pf}	Compressibility of HF, Pa ⁻¹
K	Bulk modulus of shale, GPa
T	Temperature, K
E	Young's modulus, GPa
μ	Viscosity, Pa.s
p_L	Langmuir pressure, Pa
v_L	Langmuir volume, m ³ /kg

References

- [1] J.B. Curtis, Fractured shale-gas systems. AAPG Bull. vol. 86, 2002, pp. 1921-1938.
- [2] F. Javadpour, D. Fisher, M. Unsworth, Nanoscale gas flow in shale gas sediments. J. Can. Pet. Technol. vol. 46 (10), 2007, pp. 55-61.
- [3] D. Davudov, R.G. Moghanloo, Scale-dependent pore and hydraulic connectivity of shale matrix. Energy fuels, vol. 32 (1), 2018, pp. 99-106.
- [4] B.W. Hu, J.G. Wang, K. Zhang, Z.W. Ye, A new triple-porosity multiscale fractal model for gas transport in fractured shale gas reservoirs. J. Nat. Gas Sci Eng. vol. 78, 2020, 103335.
- [5] J. Tian, D. Elsworth, Y.K. Leong, W. Li, J. Zeng, Shale gas production from reservoirs with hierarchical multiscale structural heterogeneities. J. Petrol. Sci. Eng., vol. 208, 2021, 109380.
- [6] C.N. Xu, P.C. Li, D.T. Lu, Production performance of horizontal wells with dendritic-like hydraulic fractures in tight gas reservoirs. J. Petrol. Sci. Eng. vol. 148, 2017a, pp. 64-72.
- [7] B.R. Meyer, L.W. Bazan, R.H. Jacot, Optimization of multiple transverse hydraulic fractures in horizontal wellbores. In SPE 131732, presented at the SPE unconventional gas conference, Pittsburgh, Pennsylvania, February 23-25, 2010.
- [8] W. Yu, Z. Luo, F. Javadpour, Sensitivity analysis of hydraulic fracture geometry in shale gas reservoirs. J. Petrol. Sci. Eng. vol. 113, 2014a, pp. 1-7.
- [9] B. Song, C.A. Ehlig-Economides, Rate-normalized pressure analysis for determination of shale gas well performance. In: SPE 144031, presented at the North American Unconventional Gas

- Conference and Exhibition, Woodlands, Texas, June 14-16, 2011. N.R. Warpinski, M.J. Mayerhofer, M.C. Vincent, Stimulating unconventional reservoirs: maximizing network growth while optimizing fracture conductivity. *J. Can. Petrol. Technol.* vol. 48 (10), 2009, pp. 39-51.
- [10] N.R. Warpinski, M.J. Mayerhofer, M.C. Vincent, Stimulating unconventional reservoirs: maximizing network growth while optimizing fracture conductivity. *J. Can. Petrol. Technol.* vol. 48 (10), 2009, pp. 39-51.
- [11] D.M. Jarvie, R.J. Hill, T.E. Ruble, R.M. Pollastro, Unconventional shale-gas systems: The Mississippian Barnett shale of North-central Texas as one model for thermogenic shale-gas assessment. *AAPG Bull.* vol. 97 (4), 2007, pp. 475-499.
- [12] T. Wang, S. Tian, G. Li, M. Sheng, W. Ren, Q. Liu, S. Zhang, Molecular simulation of CO₂/CH₄ competitive adsorption on shale kerogen for CO₂ sequestration and enhanced gas recovery. *J. Phys. Chem. C*, vol. 122 (30), 2018a, pp. 17009-17018.
- [13] L.N. Germanovich, D.K. Astakhov, M.J. Mayerhofer, Hydraulic fracture with multiple segments. Observations and model formulation. *Int. J. Rock Mech. Min. Sci.* vol. 34 (3-4), 1997, 097, 97. e1-e19.
- [14] W. Yu, K. Sepehrnoori, Simulation of gas desorption and geomechanics effects for unconventional gas reservoirs. In: *SPE Western Regional & AAPG Pacific Section Meeting*, Monterey, California, USA, 19-25, April, 2013b.
- [15] Z.M. Chen, X.W. Liao, C.H. Huang, X.L. Zhao, Productivity estimations for vertically fractured wells with asymmetrical multiple fractures. *J. Nat. Gas Sci. Eng.* vol. 21 (6), 2014, pp. 1048-1060.
- [16] Y. Xu, C.J. Filho, W. Yu, K. Sepehrnoori, Discrete-fracture modeling of complex hydraulic fracture geometries in reservoir simulators. In *SPE Res Eval & Eng* vol 20 (02), 2017b, pp. 403-422.
- [17] D.P. Craig, T.A. Blasingame, Constant-rate drawdown solutions derived for multiple arbitrarily-oriented uniform-flux, infinite-conductivity, or finite-conductivity fractures in an infinite-slab reservoir. In the *SPE Gas Technology Symposium*, Calgary, Alberta, Canada, May 2006.
- [18] W. Luo, C. Tang, Pressure-transient Analysis of multi-wing fractures connected to a vertical wellbore. *SPE J.* vol. 20 (02), 2015, pp. 360-367.
- [19] T.Y. Wang, S.C. Tian, W.H. Zhang, W.X. Ren, G.S. Li, Production model of a fractured horizontal well in shale gas reservoirs. *Energy & Fuels*, vol. 10, 2020a, pp.1021.
- [20] F. Javadpour, Nanopores and apparent permeability of gas flow in mudrocks (shales and siltstone). *J. Can. Pet. Technol.* vol. 48 (08), 2009, pp. 16-21.

- [21] T. Wang, S. Tian, G. Li, M. Sheng, W. Ren, Q. Liu, P. Zhang, Experimental study of water vapor adsorption behaviors on shale. *Fuel*, vol. 248, 2019a, pp. 168-177.
- [22] T.Y. Wang, S.C. Tian, Q.L. Liu, G.S. Li, M. Sheng, W.X. Ren, P.P. Zhang, Pore structure characterization and its effects on methane adsorption in shale kerogen. *Pet. Sci.* vol. 10, 2020b, pp. 1007.
- [23] M. Bahrami, M.M. Yovanovich, J.R. Culham, A novel solution for pressure drop in singly connected microchannels of arbitrary cross-section. *Int. J. Heat Mass Transfer*, vol. 50 (13-14), 2007, pp. 2492-2502.
- [24] A. Mehmani, M. Prodanovic, F. Javadpour, Multiscale, multiphysics network modeling of shale matrix gas flows. *Transp Porous Med*, vol. 99, 2013, pp. 377-390.
- [25] K. Wu, Z. Chen, X. Li, Real gas transport through nanopores of varying cross-section type and shape in shale gas reservoirs. *Chem. Eng. J.* vol. 281, 2015a, pp. 813-825.
- [26] M. Micheal, W.L. Xu, J. Jin, H.Yu, J.D. Liu, W.D. Jiang, H. Liu, H.A. Wu, A multi-scale quadruple-continuum model for production evaluation of shale gas reservoirs considering complex gas transfer mechanisms and geomechanics. *J. Pet. Sci. Eng.* vol. 213, 2022, pp. 110419.
- [27] S. Roy, R. Raju, H.F. Chuang, B.A. Cruden, M. Meyyappan, Modelling gas flow through microchannels and nanopores. *J. Appl. Phys.* vol. 93 (8), 2003, pp. 4870-4879.
- [28] N.G. Hadjiconstantinou, The limits of Navier-stokes theory and kinetic extensions for describing small-scale gaseous hydro-dynamics. *Phys. Fluids*, vol. 18(11), 2006, pp. 111301.
- [29] J.K. Holt, H.G. Park, Y. Wang, M. Stadermann, A.B. Artyukhin, C.P. Grigoropoulos, A. Noy, O. Bakajin, Fast mass transport through sub-2-nanometer carbon nanotubes. *Science*, vol. 312 (5776), 2006, pp. 1034-1037.
- [30] I.Y. Akkutlu, E. Fathi, Multiscale gas transport in shales with local kerogen heterogeneities. *SPE J* vol. 17 (04), 2012, pp. 1002-1011.
- [31] T. Wang, S. Tian, G. Li, M. Sheng, Selective adsorption of supercritical carbon dioxide and methane binary mixture in shale kerogen nanopores. *J. Nat. Gas Sci. Eng.* vol. 50, 2018b, pp. 181-188.
- [32] W. Ren, J. Guo, F. Zeng, T. Wang, Modeling of high-pressure methane adsorption on wet shales. *Energy Fuels*, vol. 33 (8), 2019, pp. 7043-7051.
- [33] R.W. Barber, D.R. Emerson, Challenges in modelling gas-phase flow in microchannels: From slip to transition. *Heat Transfer Eng.* vol. 27 (4), 2006, pp. 3-12.
- [34] A. Beskok, G.E. Karniadakis, Report: A model for flows in channels, pipes, and ducts at micro and nano scales. *Microscale Thermophys. Eng.* vol. 3 (1), 1999, pp. 43-77.

- [35] F. Civan, Effective correlation of apparent gas permeability in tight porous media. *Transp. Porous Media*, vol. 82 (2), 2010, pp. 375-384.
- [36] H. Darabi, A. Etehad, F. Javadpour, K. Sepehrnoori, Gas flow in ultra-tight shale strata. *J. Fluid Mech.* vol. 710, 2012, pp. 641-658.
- [37] M. Rahmanian, R. Aguilera, A. Kantzas, A new unified diffusion-viscous-flow-model based on pore-level studies of tight gas formations. *SPE J*, vol. 18 (01), 2013, pp. 38-49.
- [38] J. Cai, D. Lin, H. Singh, S. Zhou, Q. Meng, Q. Zhang, A simple permeability model for shale gas and key insights on relative importance of various transport mechanisms. *Fuel*, vol. 252, 2019, pp. 210-219.
- [39] J. Yao, H. Sun, D. Fan, C. Wang, Z. Sun, Numerical simulation of gas transport mechanisms in tight shale gas reservoirs. *Pet. Sci.* vol. 10 (4), 2013, pp. 528-537.
- [40] J. Zeng, J. Liu, W. Li, Y.K. Leong, D. Elsworth, J. Guo, Shale gas reservoir modeling and production evaluation considering complex gas transport mechanisms and dispersed distribution of kerogen. *Pet. Sci.* vol. 10, 2020, 1007.
- [41] S. Tian, T. Wang, G. Li, M. Sheng, Q. Liu, S. Zhang, An analytical model for shale gas transport in circular tube pores. *Int. J. Heat Mass Transfer*, vol. 127, 2018, pp. 321-328.
- [42] T. Wang, S. Tian, G. Li, P. Zhang, Analytical model for real gas transport in shale reservoirs with surface diffusion of adsorbed gas. *Ind. Eng. Chem. Res.* vol. 58 (51), 2019b, 23481-23489.
- [43] J. Warren, P.J. Root, The behavior of naturally fractured reservoirs. *Soc. Pet. Eng. J* vol. 3 (3), 1963, pp. 245-255.
- [44] J. Jiang, R.M. Younis, Numerical study of complex fracture geometries for unconventional gas reservoirs using a discrete fracture-matrix model. *J. Nat. Gas Sci. Eng.* vol. 26, 2015, pp. 1174-1186.
- [45] S.H. Lee, M. Lough, C. Jensen, Hierarchical modeling of flow in naturally fractured formations with multiple length scales. *Water Resour. Res.* vol. 37 (3), 2001, pp. 443-455.
- [46] J.E. Monteagudo, A. Firoozabadi, Control-volume method for numerical simulation of two-phase immiscible flow in two-and three-dimensional discrete-fractured media. *Water Resour. Res.* vol. 40 (7), 2004, W07405.
- [47] A. Moinfar, K. Sepehrnoori, R.T. Johns, A. Varavei, Coupled geomechanics and flow simulation for an embedded discrete fracture model. *Proceedings of the SPE Reservoir Simulation Symposium*, The Woodlands, TX, 10, 2013a, pp. 2118.
- [48] A. Moinfar, A. Varavei, K. Sepehrnoori, R. Johns, Development of a coupled dual continuum and discrete fracture model for the simulation of unconventional reservoirs. In the *SPE reservoir simulation symposium*, Woodlands, Texas, February 18-20, 2013b.

- [49] W. Ren, H.C. Lau, New rate-transient analysis for fractured shale gas wells using a Tri-linear flow model. *J. Nat. Gas Sci. Eng.* vol. 80, 2020, pp. 103368.
- [50] Y. Shi, G. Song, Productivity prediction of a multilateral-well geothermal system based on a long short-term memory and multi-layer perceptron combinational neural network. *Appl. Energy*, vol. 282, 2021, 116046.
- [51] Y.S. Wu, J. Li, D. Ding, C. Wang, Y. Di, A generalized framework model for the simulation of gas production in unconventional gas reservoirs. *SPE J* vol. 19 (05), 2014, pp. 845-857.
- [52] J. Yi, I.Y. Akkutlu, C.O. Karacan, C.R. Clarkson, Gas sorption and transport in coals: A poroelastic medium approach. *Int. J. Coal Geol.*, vol. 77, 2009, pp. 137-144.
- [53] K. Wu, X.F. Li, C. Wang, W. Yu, Z.X. Chen, A model for gas transport in micro fractures of shale and tight gas reservoirs. In: *SPE/CSUR Unconventional Resources Conference* held in Calgary, Alberta, Canada, 20-22, October, 2015b.
- [54] J. Jiang, and R.M. Younis, Hybrid coupled discrete-fracture/matrix and multicontinuum models for unconventional-reservoir simulation. *SPE J*, vol. 21 (03), 2016, pp. 1009-1027.
- [55] R.H. Zhang, L.H. Zhang, R.H. Wang, Y.I. Zhao, R. Huang, Simulation of a multistage fractured horizontal well with finite conductivity in composite shale gas reservoir through finite element method. *Energy Fuels*, vol. 30 (11), 2016, pp. 9036-9049.
- [56] Y. Xia, Y. Jin, K.P. Chen, M. Chen, D. Chen, Simulation on gas transport in shale: The coupling of free and adsorbed gas. *J. Nat. Gas Sci. Eng.* vol. 41, 2017, pp. 112-124.
- [57] L. Geng, G. Li, M. Wang, Y. Li, S. Tian, W. Pang, Z.A. Lyu, Fractal production prediction model for shale gas reservoirs. *J. Nat. Gas Sci. Eng.* vol. 55, 2018, pp. 354-367.
- [58] X. Fan, G. Li, S.N. Shah, S. Tian, M. Sheng, L. Geng, Analysis of a fully coupled gas flow and deformation process in fractured shale gas reservoirs. *J. Nat. Gas Sci. Eng.* vol. 27, 2015, pp. 901-913.
- [59] N. Zhao, J.D. McLennan, M.D. Deo, Morphology and growth of fractures in unconventional reservoirs. Presented at the Canadian unconventional resources conference, Calgary, Canada, 15 November 2011.
- [60] L. Mi, H. Jiang, J. Li, The impact of diffusion type on multiscale discrete fracture model numerical simulation for shale gas. *J. Nat. Gas Sci. Eng.* vol. 20, 2014a, pp. 74-81.
- [61] L. Mi, H. Jiang, J. Li, The investigation of fracture aperture effect on shale gas transport using discrete fracture model. *J. Nat. Gas Sci. Eng.* vol. 21, 2014b, pp. 631-635.
- [62] J. Norbeck, H. Huang, R. Podgorney, An integrated discrete fracture model for description of dynamic behavior in fractured reservoirs. In *30th-proceedings of the 9th workshop on geothermal reservoir engineering* Stanford University, Stanford, CA, 24th-26th February, 2014.

- [63] G. Sheng, Y. Su, W. Wang, A new fractal approach for describing induced-fracture porosity/permeability/compressibility in stimulated unconventional reservoirs. *J. Petrol. Sci. Eng.* vol. 179, 2019, pp. 855-866.
- [64] Y. Chen, Y. Nagaya, T. Ishida, Observations of fractures induced by hydraulic fracturing in anisotropic granite. *Rock Mech. Rock Eng.* vol. 48(4), 2015, pp. 1455-1461.
- [65] J.W. Tian, J.S. Liu, D. Elsworth, Y.K. Leong, W. Li, J. Zeng, A dynamic fractal permeability model for heterogeneous coalbed reservoir considering multiphysics and flow regimes. In *SPE/AAPG/SEG, Unconventional Resources Technology Conference*, Denver, Colorado, USA, July 2019.
- [66] T. L. Blanton, Propagation of hydraulically and dynamically induced fractures in naturally fractured reservoirs. Presented at the *SPE Unconventional Gas Technology Symposium*, Louisville, Kentucky, 18th May 1986.
- [67] E. Ozkan, M. Brown, R. Raghavan, H. Kazemi, Comparison of fractured-horizontal-well performance in tight sand and shale reservoirs. *SPE Res. Eval. Eng.* vol. 14 (02), 2011, pp. 248-259.
- [68] M. Nobakht, L. Mattar, S. Moghadam, D.M. Anderson, Simplified forecasting of tight/shale-gas production in linear flow. *J. Can. Pet. Technol.* vol. 51 (06), 2012, pp. 476-486.
- [69] W. Yu, K. Sepehrnoori, Optimization of multiple hydraulically fractured horizontal wells in unconventional gas reservoirs. In: *SPE Production and Operations Symposium* held in Oklahoma City, Oklahoma, USA, 23-26 March, 2013a.
- [70] E. Detournay, H.D. Cheng, 5-Fundamentals of poroelasticity. *Anal. Des. Meth.* vol. 140, 1993, pp. 113-171.
- [71] Y. Wu, J.S. Liu, D. Elsworth, Z.W. Chen, L. Connell, Z.J. Pan, Dual poroelastic response of a coal seam to CO₂ injection. *Int. J. Greenhouse Gas Contr.* Vol. 4 (4), 2010, pp. 688-678.
- [72] P. Cao, J.S. Liu, Y.K. Leong, A fully coupled multiscale shale deformation-gas transport model for the evaluation of shale gas extraction. *Fuel* vol. 178, 2016a, pp. 103-117.
- [73] H. Zhang, J. Liu, D. Elsworth, How sorption-induced matrix deformation affects gas flow in coal seams: a new FE model. *Int. J. Rock Mech. Min. Sci.* vol. 45 (8), 2008, pp. 1226-1236.
- [74] X. Cui, R.M. Bustin, Volumetric strain associated with methane desorption and its impact on coalbed gas production from deep coal seams. *AAPG Bull.* vol. 89 (9), 2005, pp. 1181-1202.
- [75] Y.L. Zhao, G. Lu, L.H. Zhang, Numerical simulation of shale gas reservoirs considering discrete fracture network using a coupled multiple transport mechanisms and geomechanics model. *J. Petrol. Sci. Eng.* vol. 195, 2020, pp. 107588.
- [76] M. Zhang, J. Yao, H. Sun, J.L. Zhao, D.Y. Fan, Z.Q. Huang, Y.Y. Wang, Triple-continuum

- modeling of shale gas reservoirs considering the effect of kerogen. *J. Nat. Gas Sci. Eng.* vol. 24, 2015, pp. 252-263.
- [77] E. Fathi, I.Y. Akkutlu, Matrix heterogeneity effects on gas transport and adsorption in coalbed and shale gas reservoirs. *Transp Porous Med*, vol. 80, 2009, pp. 281-304.
- [78] W. Yu, K. Sepehrnoori, T.W. Patzek, Modeling gas adsorption in Marcellus shale with Langmuir and Bet isotherms. In: Annual Technical Conference and Exhibition, Amsterdam, 27-29, October 2016.
- [79] W.N. Yuan, Z.J. Pan, X. Li, Y.X. Yang, C.X. Zhao, L.D. Connell, Experimental study and modelling of methane adsorption and diffusion in shale. *Fuel*, vol. 117, 2014, pp. 509-619.
- [80] B.W. Hu, J.G. Wang, D. Wu, H. Wang, Impacts of zone fractal properties on the shale gas productivity of a multiple fractured horizontal well. *Fractals* vol. 27 (2), 2019, pp. 11950006.
- [81] B. Wang, C. Fidelibus, An open-source code for fluid flow simulations in unconventional fractured reservoirs. *Geosciences*, MDPI, vol. 10, 2021, pp. 3390.
- [82] A.L. Lee, M.H. Gonzalez, B.E. Eakin, The viscosity of natural gases. *JPT, J. Pet. Technol.* vol. 18 (8), 1966, pp. 997-1000.
- [83] J.R. Elliott, C.T. Lira, *Introductory chemical engineering thermodynamics*; prentice-hall international series in the physical and chemical engineering sciences; prentice hall: upper saddle river, NJ, USA, 2012.
- [84] M. Mahmoud, Development of a new correlation of gas compressibility factor (Z-factor) for high pressure gas reservoir. *J. Energy Resour. Technol.* vol. 136, 2013, pp. 012903.
- [85] P.N. Azom, F. Javadpour, Dual-continuum modelling of shale and tight gas reservoirs. Presented at the SPE annual technical conference and exhibition held in San Antonio, Texas, USA, 8th -10th October, 2012.
- [86] F. Javadpour, M. McClure, M.E. Naraghi, Slip-corrected liquid permeability and its effect on hydraulic fracturing and fluid loss in shale. *Fuel*, vol. 160, 2015, pp. 549-559.
- [87] E. Fathi, A. Tinni, and I.Y. Akkutlu, Shale gas correction to Klinkenberg slip theory. In: American Unconventional Resources Conference held in Pittsburgh, Pennsylvania, USA, 5th -7th June 2012.
- [88] C.H. Guo, M.Z. Wei, H. Liu, Study of gas production from shale reservoirs with multistage hydraulic fracturing horizontal well considering multiple transport mechanisms. *PLOS One* vol. 13(1), 2018, pp. 0188480.
- [89] P. Cao, J.S. Liu, Y.K. Leong, Combined impact of flow regimes and effective stress on the evolution of shale apparent permeability. *Journal of Unconventional Oil and Gas Resources* vol. 14, 2016b, pp. 32-43.

- [90] W. Li, J.S. Liu, J. Zeng, Y.K. Leong, D. Elsworth, J.W. Tian, L. Li, A fully coupled multidomain and multiphysics model for evaluation of shale gas extraction. *Fuel* vol. 278, 2020, pp. 118214.
- [91] D.W. Peaceman, Interpretation of well-block pressures in numerical reservoir simulation with nonsquare grid blocks and anisotropic permeability. *SPE J.* vol. 23, 1983, pp. 531-543.
- [92] W. Yu, K. Sepehrnoori, Simulation of gas desorption and geomechanics effects for unconventional gas reservoirs. *Fuel* vol. 116, 2014b, pp. 455-464.
- [93] M. Micheal, W.L. Xu, H.Y. Xu, J.N. Zhang, H.J. Jin, H.Yu, H.A. Wu, Multi-scale modelling of gas transport and production evaluation in shale reservoir considering crisscrossing fractures. *J. Nat. Gas Sci. Eng.* vol. 95, November 2021, pp. 104156.
- [94] J.F. W. Gale, S.E. Laubach, J.E. Olson, P. Eichhubl, A. Fall, Natural fractures in shale: a review and new observations. *AAPG Bull.* vol. 98 (11), 2014, pp. 2165-2216.
- [95] A. Yaghoubi, Hydraulic fracturing modeling using a discrete fracture network in the Barnett Shale. *Int. J. Rock Mech. Min. Sci.* vol. 119, 2019, pp. 98-108.
- [96] F.M. David, History of the Newark East field and the Barnett shale as a gas reservoir. *AAPG Bullentin*, vol. 91 (4), April, 2007, pp. 399-403.
- [97] D. Fan, A. Etehadtavakkol, Semi-analytical modeling of shale gas flow through fractal induced fracture networks with microseismic data. *Fuel* vol. 193, 2017, pp. 444-459.
- [98] L.F. Ruppert, S. Richard, P.B. Tomasz, H. Lilin, B. M. Yuri, F.R. David, A.L. Leo, A USANS/SANS study of the accessibility of pores in the Barnett Shale to methane and water. *Energy & Fuels* vol. 27 (2), 2013, pp. 772-779.
- [99] J. Zhang, C.T. Wei, J.L. Zhao, W. Ju, Y.L. Chen, L.S. Tamehe, Comparative evaluation of the compressibility of middle and high rank coals by different experimental methods. *Fuel* vol. 245, 2019, pp. 39-51.
- [100] Y. Tan, Laboratory characterization of fracture compressibility for coal and shale gas reservoir rocks: a review. *Int. J. Coal Geol.* vol. 204, 2019, pp. 1-17.
- [101] G.J. Sang, D. Elsworth, X.M. Miao, X.B. Mao, J.H. Wang, Numerical study of a stress dependent triple porosity model for shale gas reservoirs accommodating gas diffusion in kerogen. *J. Nat. Gas Sci. Eng.* vol. 32, 2016, pp. 423-438.

Instant Data-Driven Robotics Fabrication of Light-Transmitting Ceramics: A Responsive Computational Modeling Workflow

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Abstract— Current architectural façade design practices incorporate various daylighting and solar radiation analysis methods. These emphasize the impact of geometry on façade design. There is scope to extend this knowledge into methods that address material translucency, porosity, and form. Such approaches can also achieve these conditions through adaptive robotic manufacturing approaches that exploit material dynamics within the design, and alleviate fabrication waste from molds, ultimately accelerating the autonomous manufacturing system. Besides analyzing the environmental solar radiant in building facade design, there is also a vacancy research area of how lighting effects can be precisely controlled by engaging the instant real-time data-driven robot control and manipulating the material properties. Ceramics carries a wide range of transmittance and deformation potentials for robotics control with the research of its material property. This paper presents one semi-autonomous system that engages with real-time data-driven robotics control, hardware kit design, environmental building studies, human interaction, and exploratory research and experiments. Our objectives are to investigate the relationship between different clay bodies or ceramics' physio-material properties and their transmittance; to explore the feedback system of instant lighting data in robotic fabrication to achieve precise lighting effect; to design the sufficient end effector and robot behaviors for different stages of deformation. We experiment with architectural clay, as the material of the façade that is potentially translucent at a certain stage can respond to light. Studying the relationship between form, material properties, and porosity can help create different interior and exterior light effects and provide façade solutions for specific architectural functions. The key idea is to maximize the utilization of in-progress robotics fabrication and ceramics materiality to create a highly integrated autonomous system for lighting facade design and manufacture.

Keywords— light transmittance, data-driven fabrication, computational design, computer vision, gamification for manufacturing.

Measuring Sustainability Performance of Digital Supply Chains in the era of Industry 4.0

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Abstract-- Measuring the sustainability performance of supply chains is fundamental to creating sustainable supply chains and addressing economic, social, and environmental challenges. However, with the emergence of digitalization of the supply chain and industry 4.0 can help enhance sustainability in the supply chain there are very few studies in this area. This research aims to focus on establishing the links between digital technologies and the various dimensions of sustainability performance (economic, social, and environmental performance), which help improve the understanding of the performance implications of digital technologies in Industry 4.0. This research surveys 71 peer-reviewed articles that were retrieved through a systematic literature review. This research identifies absence of scientific discourse employing empirical techniques and a lack of investigations on the 3 dimensions of sustainability together.

Keywords— Digital supply chains, Industry 4.0, digital technology, sustainability

Research Context

Technology has dramatically changed our life and business in many ways in which we can now access, store, and process a massive amount of data. Traditionally, firms make decisions based on data that are directly originates from their day-to-day operations and transactions. In recent times such data are available in much larger scopes and in much greater details which had given managers a great of deal in decision making. In a rapidly changing world, businesses compete to serve customers with faster, cheaper, and higher quality products. As a result, the competition has shifted from firm vs firm to supply chain vs supply chain [1]. Making it vital for a firm to continuously improve, upgrade and invest in its supply chain. In the past decade, digital technologies have penetrated and improved every aspect of the supply chain, including procurement, manufacturing, distribution, and customer/supplier relations [2]. Digital technologies have profoundly altered the way people communicate and interact with their surroundings. Technological novelties and personal gadgets, such as mobile devices, personal computers, self-driving cars, drones, advanced television units, wearable devices, smartphones, smartwatches and many more gadgets have changed the way how societies access and exchange information [3]. These emerging new technologies affect every industry including supply chains and logistics services. This adoption and reliance on digital technologies to perform business activities is referred to as “digital transformation” or “digitalization.” These terms describe the integration of digital technology into all business areas to create new or modify existing business processes, culture and customer experiences, fundamentally changing how firms operate and deliver value to customers [3]. This digitization in supply chain management as put huge pressure on organizations to change their processes and strategies. Hence it is crucial for managers to understand the implication of digitization on their organization and employees [4]. The effect of digitization includes varied impacts on economy as a whole; create tremendous opportunities and challenges for businesses. In the current world of globalized digitization is not a choice but an imperative for all businesses across all industries. Manufacturing processes and work, business model, products and services are the main targets of

digitization [5]. According to [2], digital transformation is the process of organizational change in which digital technologies (such as cloud computing, 3D printing, internet of things, big data analysis) are used to change, how a company generates value in its products, how it interacts with its suppliers, partners and customers and how it competes in global market. Hence digital supply chain management can be defined as powerful innovative technologies that can change the traditional way of doing various processes of supply chain like supply chain planning, task execution, interacting with all the participants of supply chain, achieving integration among the members of supply chain, and enabling new business model.

A Digital Sustainable Supply Chain (DSSC) is a smart, value-driven, efficient process to generate new forms of revenue and business value for organizations and to leverage new approaches with novel technological and analytical methods. DSSC is not about whether goods and services are digital or physical, it is about the way how supply chain environmentally friendly and processes are managed with a wide variety of innovative technologies [3]. Technological progress has greatly increased the importance of big data in the process of decision-making of companies [6]. According to [2] sustainable development in manufacturing companies has had both challenges and opportunities because of the use of deep integration of intelligent digital technologies. This has changed the traditional operations and production methods used and proposed potential improvement on product development, production efficiency and customer service.

However, emerging technologies may further increase the competitive dynamics in business environments and impose financial and environmental burdens on manufacturing firms [7]. In this case, digital technologies may lead to unintended negative consequences on sustainable development. It should be noted that how digital technologies influence sustainability performance in terms of economic, social, and environmental performance is still under-investigated [2]. [1] recognized the role of advanced digital technologies for Industry 4.0 in supply chain relationships, which enable massive information gathering and disposal and excellent cooperation and integration. [2] argued that the effect of digital technologies on sustainability performance needs to be realized through a well-established supply chain platform.

The term "Industry 4.0" was first coined at a trade fair organized in Hannover, Germany in 2011 [8]. Industry 4.0 technologies can assist companies to achieve integrated, flexible, and diversified production systems that will lead to the production of customized products [9]. Industry 4.0 has become a buzzword that describes the trend towards digitalization and automation of manufacturing. It allows products, machines, components, individuals, and systems to create a smart network so that it can integrate cyber-physical systems to act quickly by linking information and physical memory to the smart network for faster and more effective service environments [9]. Organizations can allocate resources efficiently on a real-time basis by employing Industry 4.0 technologies, it will allow efficient resource allocation due to digitalization of the supply chain process. Additionally, [10] points out that there are obstacles to overcome in supply chains 4.0 apart from technical aspects or non-technical challenges. Although, these technologies will support improvement of customer's satisfaction, increases efficiency, integration, transparency, and financial improvements. Hence, it is of importance to measure performances of this technology in industry 4.0.

Triple bottom line can be used to evaluate sustainability performance from multiple aspects [11]. With global climate change, both producers and consumers have an increasing awareness of sustainability, which urges production activities along supply chains to become greener and has induced the transition of conventional supply chains towards sustainable ones [12]. Focusing on the economic, environmental, and social impacts of products throughout their life cycle, sustainable supply chain management (SSCM) aims to integrate the issue of sustainability into the management of entire supply chains [13]. Business practices can be improved via SSCM to promote the sustainability of supply chains [14]. [15] investigated strategies for balancing the economic and environmental performances of firms while reducing environmental externalities. SSCM has also attracted attention from policymakers and practitioners worldwide. A pillar of SSCM is the measurement of sustainability performance of supply chains and the quantification of their determinants as well as consequences, according to which follow-up actions could be taken to promote the performance [11].

Several authors [16,17,18] argued that sustainability extends beyond the boundaries of any single firm, and harmful impacts occur across all stages of products lifecycle [19]. Policymakers and government are increasing pressures on environmental sustainability as such made companies to look for means to reduce their environmental impact either by reducing pollution, encouraging recycling, reuse or raising energy efficiencies as this firms play significant role in high carbon emissions because of energy consumption used during production of goods and services [20]. However, investing in environmental management often increases costs without resulting in financial benefits. Therefore, the vital question from corporate managers is now facing is how to minimise environmental impacts without reducing firm financial performance [21]. Before the 1990s the importance of firm competitiveness in eco-innovation and environmental sustainability was not paramount as it is in this modern age with massive pressures from regulatory authorities on firms to adhere to environmental sustainability [22].

Measuring sustainability performance of supply chains is essential in sustainable supply chain management and various researcher have researched about this. However, with the emerging of digitalization of supply chain and industry 4.0 which it's robust to compute and analyse large data to help operational function, there are very few studies in this area which this study will contribute to relevant research area in measuring sustainability performance of digital supply chain. This study will focus on establishing the links between digital technologies and the three dimensions of sustainability performance (economic, social, and environmental performance), which will expatiate more on the performance implications of digital technologies in Industry 4.0. The research will further investigate the mediating effect of digital supply chain on the relationships between digital technologies and economic, social, and environmental performance, thus establishing a mechanism explaining how digital technologies relate to social, economic, and environmental performance. There are numbers of weighing options available like factor analysis data envelopment analysis and unobserved components model or analytical hierarchy process, budget allocation process conjoint analysis can all provide methods of assigning weights however, this research will adopt the data envelopment analysis (DEA) technique to empirically examine the sustainability performances of digital supply chain in the manufacturing industry of United Kingdom between 2011–2021.

Theoretical Background

Sustainability performance is usually assessed from the viewpoint of the triple bottom line. The three dimensions need to be integrated into a unified framework for performance assessment. Besides, various factors surrounding supply chains and their management also affect the performance assessment [2]. Technology has emerged as an important driver of sustainable operations [23]. [24] observed that Industry 4.0 based technologies can make operations sustainable, environmentally friendly, and economically feasible. The theoretical foundation for our research study is drawn from the organisation information processing theory (OIPT) [25]. OIPT indicates that an organization as an open social-economical system can achieve superior performance by improving its informational processing capabilities and information quality [25]. Digital technologies form the internal information architecture, which represents a firm's information processing capabilities. Moreover, supply chain platforms serve as the channel for the information exchange between supply chain partners, which is regarded as a major source of external information. The enhanced information processing capabilities complementing the external supply chain information led to the sustainable development of manufacturing firms. Therefore, based on OIPT, this study examines how digital technologies are applied in supply chain relationships and the resulting impact on economic and environmental performance.

OIPT highlights that the organization's information processing capabilities and information requirements should be matched with the business environment. It is suggested that the performance of implementing advanced digital technologies and supply chain platforms may be affected by environmental conditions [26,27]. [28] refers environmental dynamism to be the instability or volatility of a firm's environment. Information-processing needs are determined by various environmental contexts in which the organization is located, while information processing capabilities refer to the

configurations of resources, technology architecture and other work units that facilitate information collection, processing, and distribution [29,30]. To cope with environmental dynamism or the frequency of changes in environmental factors, organizations can adopt two strategies to support decision making and improve performance: (1) acquire a greater amount of high-quality information to reduce the effect of dynamism and (2) devote more efforts to improving information processing capabilities for effective decision making [31]. Recently, OIPT has been extensively applied in information systems [32] technology integration [33], production control systems [34], maintenance management [35] and supply chain management [26,31]. Moreover, digital supply chain platforms provide information exchange channels to access external information. Thus, digital technologies drive supply chain platforms to satisfy information requirements caused by environmental dynamism [2].

This research seeks to explore the integration of social, economic, and environmental issues in the management of digital supply chains from an operations management perspective. According to [36] resource-based view theory is one of the most prominent and powerful theories for describing, explaining, and predicting organizational relationships. They also defined RBV as bundles of tangible and intangible assets, including a firm's management skills, its organizational processes and routines, and the information and knowledge it controls that can be used by firms to help choose and implement strategies. [37] further explains the theory in analysing the intangible firm resources assets to be the capability of big data analytics, data quality management, and data usage experience and portrays physical IT infrastructure as a tangible resource which both can grow firms IT capability that can lead to competitive advantage and ultimate superiority performance. [20] posits on RBV is that firms can achieve sustainable competitive advantages by allocating its resources and capabilities in environmentally friendly business activities. Most of the existing literature investigates the outcomes of digital technology asset deployment through the lens of the resource-based view or dynamic capability theory [38,39]. They argue that the competitive advantage of a firm mostly hangs on the use of their tangible and intangible properties and resources.

Decision-making based on innovative technologies improves the information processing capacities of internal manufacturing processes. Supply chain channels are assumed to be stable and reliable. However, COVID-19 has disrupted traditional channels like retail channels due to lockdown, and demand has shifted to e-commerce channels. Sustainability constitutes one of the critical drivers of innovation as such this research presents industry specific data from a key global manufacturing sector of the country on a commercially sensitive subject.

Research Objective

In the new era of Industry 4.0, the development and adoption of digital technologies has become one of the most frequently trending topics in both academic and professional areas [2]. According to [1] the focus of Industry 4.0 is on digital technologies that will cause significant impacts on supply chains. According to [40], these new technologies will radically change supply chain operations and they need to be aligned to customer demands. Moreover, these new technologies, especially IoT and Cyber-Physical Systems (CPS), will generate impacts on products and services, business models, markets, economy, work environment and people, and organizational skills, deeply changing supply chains [41]. Few studies [41,42,2] have empirically explored how these digital technologies influence sustainability through the establishment of digital supply chains platform. One of the important features of sustainability performance measurement of supply chain is the involvement and impact of multi dimensions of supply chains [11]. The attributes of the triple bottom line dimensions (environmental, social, and economic) of sustainability will be considered for sustainability assessment in digital supply chain. Many studies have researched on sustainability, the majority do not take considerations of the three dimensions of sustainability. [11] study only concentrate on environment using the input-output modelling approach to account for the multidimensional and transactional features in measuring sustainability performance of supply chain. Hence, this study aims to examine the gap in measuring the sustainability performance of digital supply chains in the era of Industry 4.0 via the following objectives:

1. Assessing the sustainability performance of digital technologies in digital supply chain using input and output modelling approach.
2. Evaluate the relationship between digital technologies for Industry 4.0 and the three dimensions of sustainability performance (economic, social, and environmental performance).
3. Measuring Impact of digital technologies on Corporate social responsibility and digital supply chain.

Research Questions

Main research question: What is the impact of sustainability performance of digital supply chains in the era of Industry 4.0?

Sub-questions

1. What is the impact of sustainability performance of digital technologies in digital supply chain using input and output modelling approach?
2. What is the relationship between digital technologies for Industry 4.0 and the three dimensions of sustainability performance (economic, social, and environmental performance)?
3. What is the moderating mechanism of digital technologies capability on the relationship between CSR and digital supply chain?

One of the important features of sustainability performance measurement of supply chain is the involvement and impact of multi dimensions of supply chains [11]. The attributes of the triple bottom line dimensions (environmental, social, and economic) of sustainability will be considered for sustainability assessment in digital supply chain. Many studies have researched on sustainability, the majority do not take considerations of the three dimensions of sustainability. [11] study only concentrate on environment using the input-output modelling approach to account for the multidimensional and transactional features in measuring sustainability performance of supply chain. This study will be using this approach to measure the three aspect of triple bottom line using same input-output modelling approach, which is also can be adapted to evaluate social, economic, and environmental using data envelopment analysis (DEA) technique.

How digital technologies for Industry 4.0 be evaluated using the three dimensions of sustainability performance (economic, social, and environmental performance)? How digital technologies for Industry 4.0 are applied in supply chain relationships and the resulting impact on the three dimensions of sustainability performance (economic, social, and environmental performance)? This question helps to understand the performance implications of digital technologies in industry 4.0 by establishing a mechanism on how digital technology relate to the three dimension which made this research unique and different to previous researchers. [2] focus on economics and environmental performance which was conducted in the emerging market (China)while this research will take the 3 dimensions of economic, social and environmental perspectives in developed markets (UK) to evaluate the impact of digital technologies in industry 4.0.

What is the moderating mechanism of digital technologies capability on the relationship between CSR and digital supply chain? [43] study only consider big-data analytics capability as a moderator to explore the effect of CSR on green supply chain, although other previous studies pointed out that big-data analytics capability play an increasingly important role in decision-making processes and operation management [44,43] but less have considered other digital technologies such AI cloud computing and

rest which this research will reliably considered the CSR-digital supply chain management relationship by revealing the moderating effect of digital technologies capability in industry 4.0 era.

Methodology

According to [45] research methodology can be described as successive actions taken by a researcher in analysing a theme in line with the project objectives and goals. Research methodology describes the overall method to a research process. Earlier research used partial least-squares (PLS) regression-based structural equation modelling method to solve the simultaneous equation. But this research will adopt input and output analysis model using DEA technique as this will help in efficiency measurement of multiple input and output taking from multi sector of a manufacturing industry as adopted in [11]. DEA employ multiple inputs to produce multiple outputs which forms the Decision-Making Units (DMUs).

Due to the multidimensional nature of supply chain performance assessment, multi-criteria decision making (MCDM), and multi-objective mathematical programming approaches have been most often chosen [46]. Of the commonly used tools, DEA has gained popularity in the past decades [47]. Established within a multi-input multi-output framework, DEA can construct composite indicators that can simultaneously and holistically reflect multiple impacts of supply chains. In addition, DEA can further identify peers with the best practice which are located on the production frontier for benchmarking purposes. Given these strengths, DEA has been increasingly applied to evaluate supply chain performance. [11] used the DEA technique to account for the multidimensional characteristic of supply chains in a global context. DEA is useful in modelling the multi-input multi-output digital supply chain framework and can well serve the benchmarking purpose. It can cope very well with multiple input/multiple output processes. It is a non-parametric multivariate method based on linear programming, which has proven its efficiency in uncovering relationships that remain hidden for other methodologies, especially when no clear profit objectives are in place.

DEA is suitable for the proposed analysis since, while there is a debate on which social and environmental dimensions should be emphasized in a CSP index, and accordingly be awarded a higher weight on aggregation, DEA constructs an endogenous set of weights by letting them be determined as part of an optimal solution to a formal aggregation problem. In other words, DEA assigns a set of weights to each firm, awarding higher weights to those dimensions where a firm score better hence it gives the percentage by which a particular sub-optimal firm should improve in a certain dimension to achieve the best practice. It has been said that the DEA index casts each firm in the best possible light, and this property allows for comparisons between firms with different business organisation behaviour [48].

Input and Output Analysis model

Various materials and resources are used by firms in production of goods along with digital supply chain of such production while generating social impact, environmental pollution and economic value as by-product. This research will consider capital, energy and labour as inputs. Value added will be used to measure the economic output, CSR as output and production activities affect the environment by producing a variety of pollutant to be represented as undesirable output.

The measures for digital technologies would adapt from [49,2,4], which include the Internet of Things, cloud computing, big data analytics and artificial intelligent. Their studies used a reflective model to measure digital technologies. In the era of Industry 4.0, these innovative technologies can be integrated and interconnected to realize a more coherent effect which implies that the items for digital technologies are highly correlated [2].

Data Collection

The Data used for this study will be both primary and secondary data. Primary data will be obtained from questionnaire administered to the key staffs in the manufacturing sector and their supply chain customers. While secondary data will be obtained from publication of listed manufacturing companies in London stock exchange, Annual Statement of Accounts. Others may be obtained from international organisation data (UNIDO, FTSE Russel), data from Thomas Reuters and Bloomberg.

Data Sample

Theoretical sampling and snowballing techniques will be used to ensure only critical cases that help address the research questions are included [45]. The study will use the large population of companies listed in the FSTE All Share Index UK stock exchange market. The sample is composed of publicly listed manufacturing firms in the UK within year 2011 to 2021. Gathering contact information of the firms in the target sampling for distribution and collection of created online surveys which will be sent via emails and promised to keep the data confidential

Academic contribution

The integration of economic, social and environmental dimensions helps to provide a full picture of the sustainability of digital supply chain. These studies will make significant contribution to the digital supply chain management literature, the phenomenon of fourth industrial revolution that is transforming the environmental, social, and financial strategic positions of digital supply chains, a gap which this research aims to address.

This paper contributes to the literature in at least three ways. First, the study will investigate sustainability performance of digital technology at the developed market level. In contrast to other studies that have researched on sustainability in developing market where technology development and usage impact is still low and used selected few digital technologies while omitting the social impact in the sustainability performance measurement [2,40,4]. Secondly, the study contributes to the literature on digital supply chains by looking innovatively in the methodology using an input-output analysis (IOA) modelling approach in sustainability measurement by using data envelopment analysis (DEA) technique, to evaluate social, economic, and environmental dimensions. [11] study only concentrate on environment using the input-output modelling approach to account on the multidimensional and transactional features in measuring sustainability performance of supply chain and without the digital technology measurement this is the novelty of this research. [2] reveal in his studies that there are still very low studies that have address the framework, establishment and benefit of digital supply chain. Thirdly, this research adds to the literature of organisational information processing theory. The volume of information available to managers to make decision are getting high and this needs greater visibility to ensure decision making is effective. [25] points that the lack of information processing culture in an uncertain environment generate significant cost for the firm. Fourth, this study will serve as a reference for the literature on CSR-digital supply chain management relationship by revealing the moderating effect of digital technologies capability in industry 4.0 era. Some previous studies have pointed out that big-data analytics capability play an increasingly important role in decision-making processes and operation management [44,43]. Thus, this study contributes to the literatures of CSR and DSCM by empirically testing the moderating effect of digital technologies capability on the effect of external CSR on DSCM.

Policy contribution

Managers involved in supply chains to adapt performance measurement according to the organizational context and stakeholders' requirements need to understand the environment they are operating. This is aligned with [50] assertion that managers managing supply chain performance measurement must respect the context and its dynamics in which the supply chain is operating. In this sense, the triple bottom line approach seems to be more suitable to be considered to measure supply chains in the industry 4.0 era, taking into consideration that this phenomenon is more than only measuring sustainability performance with in-depth to innovative supply chain which digitalisation implementation accord.

However, sustainability measurement is a relevant topic related to managerial issues on the industry 4.0 phenomenon, this paper aims to look at the theoretical approach with regards to how to measure sustainability performance of digital technologies in supply chains of Industry 4.0 context. This is an identified gap by [1] in their further research recommendation and this can significantly contribute to the practitioners in Industry 4.0 as well as to researchers who need deeper theoretical insights to develop future empirical studies. The proposal is built based on the theoretical background of sustainability performance measurement, and the dimensions of digital supply chains in industry 4.0.

The results from this research are expected to help policy makers monitor the progress of digital supply chain of industry 4.0 towards sustainable practices in the 3 sustainable approaches. In the era of Industry 4.0, front-end technologies such as the Internet of Things, cloud computing, big data and analytics have been adopted to gain competitive advantages [49]. To promote sustainable development, manufacturing firms are recommended to use these digital technologies to enhance their economic and environmental sustainability. It should be recognized that operations and environmental management activities in the present business environment are highly information intensive. Firms that obtain accurate and real-time information can thus have superiority in competition. The adoption of digital technologies for Industry 4.0 is primarily for collecting and processing information related to products and production, thereby supporting decision making effectively and efficiently. A digitally enabled technology infrastructure will be a necessary choice for manufacturing firms to obtain the success of both operations and its sustainable performances.

Reference

1. Buyukozkan, G. and Gocer, F. (2018) "Digital Supply Chain: Literature review and a proposed framework for future research", *Computers in Industry*, Vol.97, pp. 157-177.
2. Li, Y., Dai, J. and Cui, L. (2020) 'The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model', *International Journal of Production Economics*, 229, pp. 107777.
3. De Giovanni, P., 2021. Smart Supply Chains with vendor managed inventory, coordination, and environmental performance. *European Journal of Operational Research*, 292(2), pp.515-531.
4. Benzidia, S., Makaoui, N. and Bentahar, O., 2021. The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance. *Technological Forecasting and Social Change*, 165, p.120557.
5. Wantao Yu, Chee Yew Wong, Roberto Chavez, Mark A. Jacobs 2021. Integrating big data analytics into supply chain finance: The roles of information processing and data-driven culture. *International Journal of Production Economics*. 236.
6. Chan, H.k., Yee R.W.Y., Dai, J., Lim, M.K., (2016). The moderating effect of environmental dynamism on green product innovation and performance., *International Journal of Production Economics*. 181, 384-391.
7. Kiel et al., D. Kiel, J.M. Müller, C. Arnold, K. (2017) Voigt Sustainable industrial value creation: benefits and challenges of industry 4.0 *International Journal Innovation Management*, 21 (8).
8. Kagermann, H., Wahlster, W. and Helbig, J. (2013), "Recommendations for implementing the strategic initiative INDUSTRIE 4.0", Acatech, Frankfurt, available at: <https://www.acatech.de/Publikation/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-finalreport-of-the-industrie-4-0-working-group/>.
9. Ricardo, C. and Santos-deLeón, N., 2020. Sustainable Supply Chain in the Era of Industry 4.0 and Big Data: A Systematic Analysis of Literature and Research. *Sustainability*, 12(10), p.4108.
10. Wu, L., Yue, X., Jin, A. and Yen, D.C. (2016), "Smart supply chain management: a review and implications for future research", *The International Journal of Logistics Management*, Vol. 27 No. 2, pp. 395-417, doi: 10.1108/IJLM-02-2014-0035.
11. Wang, H., Pan, C., Wang, Q. and Zhou, P. (2020) 'Assessing sustainability performance of global supply chains: An input-output modelling approach', *European Journal of Operational Research*, 285(1), pp. 393-404.

12. O'Rourke, D. (2014). The science of sustainable supply chains. *Science*, 344(6188), 1124-1127.
13. Gupta, S., & Palsule-Desai, O. D. (2011). Sustainable supply chain management: Review and research opportunities. *IIMB Management Review*, 23(4), 234-245
14. Min, H., & Kim, I. (2012). Green supply chain research: past, present, and future. *Logistics Research*, 4(1), 39-47.
15. Ding, H., Liu, Q., & Zheng, L. (2016). Assessing the economic performance of an environmentally sustainable supply chain in reducing environmental externalities. *European Journal of Operational Research*, 255(2), 463-480.
16. Linton, J., Klassen, R., Jaraman, V., 2007. Sustainable supply chains: An introduction *Journal of Operation Management*. 25, 1075–1082.
17. Seuring, S., Gold, S., 2013. Sustainability management beyond corporate boundaries: from stakeholder to performance. *Journal of Cleaner Production*. 56, 1–6.
18. Winter, M., Knemeyer, A.M., 2013. Exploring the integration of sustainability and supply chain management. *International Journal of Physical Distribution and Logistics Management*. 43, 18–38.
19. Qorri, A., Mujkić, Z., & Kraslawski, A. (2018). A conceptual framework for measuring sustainability performance of supply chains. *Journal of Cleaner Production*, 189, 570-584.
20. Alam Samsul, Muhammad Atif, Chu Chien-Chi, Ugur Soytas (2019). Does corporate R&D investment affect firm environmental performance? Evidence from G-6 countries. *Energy Economics*, Volume 78, February 2019, Pages 401-411
21. Lee, K.-H., Wu, Y., 2014. Integrating sustainability performance measurement into logistics and supply networks: A multi-methodological approach. *Br. Account. Rev.* 46, 361–378.
22. Chen, C.-M. (2014). Evaluating eco-efficiency with data envelopment analysis: an analytical re-examination. *Annals of Operations Research*, 214(1), 49-71.
23. Dubey R., T. Papadopoulos, A. Gunasekaran, N. Altay, S.J. Childe, S. Fosso-Wamba (2017). The role of Big Data in explaining disaster resilience in supply chains for sustainability *Journal of Cleaner Production*, 142 pp. 1108-1118
24. Wang G., A. Gunasekaran, E.W.T. Ngai, T. Papadopoulos (2016). Big data analytics in logistics and supply chain management: certain investigations for research and applications. *International Journal of Production Economics*. 176 pp. 98-110
25. Premkumar G., K. Ramamurthy, C.S. Saunders (2005). Information processing view of organizations: an exploratory examination of fit in the context of interorganizational relationships. *Journal of Management Information System*. 22 (1) pp. 257-294
26. Cegielski, C.G., L. Allison Jones-Farmer, Y. Wu, B.T. Hazen (2012). Adoption of cloud computing technologies in supply chains: an organizational information processing theory approach *International Journal of Logistics Management*., 23 (2), pp. 184-211
27. Mithas, S., A. Tafti, W. Mitchell (2013), How a firm's competitive environment and digital strategic posture influence digital business strategy *MIS Q.* pp. 511-536
28. Azadegan, A., P.C. Patel, A. Zangouinezhad, K. Linderman (2013). The effect of environmental complexity and environmental dynamism on lean practices *Journal Operation Management*, 31 (4), pp. 193-212
29. Galbraith, J. R. (1974). *Organization design: An information processing view. Interfaces*, 4(3), 28-36.
30. Tushman, M.L., D.A. (1978). Nadler Information processing as an integrating concept in organizational design *Academy Management Review*, 3 (3) pp. 613-624
31. Fan, H., Li, G., Sun, H., & Cheng, T. C. E. (2017). An information processing perspective on supply chain risk management: Antecedents, mechanism, and consequences. *International Journal of Production Economics*, 185, 63-75.
32. Wong, C.W. K.H. Lai, T.C.E. Cheng, Y.V. Lun (2015). The role of IT-enabled collaborative decision making in inter-organizational information integration to improve customer service performance *International Journal. Production Economics*, 159, pp. 56-65
33. Stock, G.N. & M.V. Tatikonda (2008). The joint influence of technology uncertainty and interorganizational interaction on external technology integration success *Journal of Operation Management*., 26 (1) pp. 65-80
34. Gong, Q., Y. Yang, S. Wang (2014). Information and decision-making delays in MRP, KANBAN, and CONWIP *International Journal Production Economics*, 156, pp. 208-213

35. Swanson L (2003). An information-processing model of maintenance management *International Journal Production Economics*, 83 (1), pp. 45-64
36. Barney, J., Ketchen, D. and Wright, M., 2011. The Future of Resource-Based Theory. *Journal of Management*, 37(5), pp.1299-1315.
37. Kwon, O., Lee, N. and Shin, B., 2014. Data quality management, data usage experience and acquisition intention of big data analytics. *International Journal of Information Management*, 34(3), pp.387-394.
38. Lee, N.C. Reconciling integration and reconfiguration management approaches in the supply chain *Int. J. Prod. Econ.* (2021), 10.1016/j.ijpe.2021.108288
39. Matarazzo, M L. Penco, G. Profumo, R. Quaglia Digital transformation and customer value creation in Made in Italy SMEs: a dynamic capabilities perspective *J. Bus. Res.*, 123 (2021), pp. 642-656
40. Zhan, Y., Kim H. Tan 2020. An analytic infrastructure for harvesting big data to enhance supply chain performance. *European Journal of Operational Research*, 281, 559-574.
41. Acharya A., S.K. Singh, V. Pereira, P. Singh (2018). Big data, knowledge co-creation and decision making in fashion industry. *International Journal of Information Management*. 42 pp. 90-101
42. Bienhaus, F. and Haddud, A. (2018). "Procurement 4.0: factors influencing the digitization of procurement and supply chains", *Business Process Management Journal*, Vol.24 No.4, pp. 965-984.
43. Chen xiao Wang, Qingpu Zhang, Wei Zhang. (2020). Corporate social responsibility, green supply chain management and firm performance: The moderating role of big-data analytics capability. *Research in Transportation Business & Management*. Volume 37.
44. Dubey, R., Gunasekaran, A., Childe, S., Fosso Wamba, S., Roubaud, D. and Foropon, C., 2019. Empirical investigation of data analytics capability and organizational flexibility as complements to supply chain resilience. *International Journal of Production Research*, 59(1), pp.110-128.
45. Saunders, M., Lewis, P. and Thornhill, A., 2007. *Research methods for business students*. Harlow: Financial Times/Prentice Hall.
46. Brandenburg, M., Govindan, K., Sarkis J., & Seuring, S. (2014). Quantitative model for sustainable supply chain management. *Developments and directions*. *European Journal of Operational Research*. 233(2), 299-312.
47. Zhou, P., Yang, Y., Chen, Y., Zhu, J., (2018). Data envelopment analysis application in sustainability: The origins, development and future directions, *European Journal of Operational Research*, 264(1), pp. 1-16.
48. Belu, C., 2009. Ranking Corporations Based on Sustainable and Socially Responsible Practices. A Data Envelopment Analysis (DEA) Approach. *Sustainable Development*, Volume 17, pp. 257-268.
49. Dalenogare L.S., G.B. Benitez, N.F. Ayala, A.G. Frank (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*. 204 pp. 383-394
50. Cuthbertson, R. and Piotrowicz, W. (2011) "Performance measurement systems in supply chains", *International Journal of Productivity and Performance Management*, Vol.60 No.6, pp.583-602.
51. Adel Hatami-Marbini, Saber Saati & Seyed Mojtaba Sajadi (2018). Efficiency analysis in two-stage structures using fuzzy data envelopment analysis. *Central European Journal of Operations Research* volume 26, pages909–932.
52. Adel Hatami-Marbini, Mehdi Toloo (2019). Data envelopment analysis models with ratio data: A revisit *Computers & Industrial Engineering* Volume 133, July 2019, Pages 331-338

Characterization of $\text{Na}_{0.5}\text{Bi}_{0.5}\text{TiO}_3$ Prepared by Hydrothermal Method for Photocatalytic Applications

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Abstract—Sodium bismuth titanate ($\text{Na}_{0.5}\text{Bi}_{0.5}\text{TiO}_3$, NBT) ceramics have been prepared by using a simple hydrothermal method. Low temperature process of thermal treatment was conducted to obtain a highly dense morphology NBT, using high-purity oxides and carbonates as the initial precursors. The presence of well-crystallized NBT in the rhombohedral phase was also found at hydrothermal temperatures above 180°C . A concentration of at least 10 M NaOH and a reaction time of at least 24 hours were needed to attain maximum perovskite phase. Xray diffraction, Raman spectroscopy, Infrared spectroscopy, and SEM analysis confirm the structure, phase, morphology, and composition. NBT ceramics exhibit the typical characteristics of relaxor ferroelectrics, with a diffusion exponent γ of up to 1.5 to promote their applications in micro-electromechanical and energy harvesting systems. The photocatalytic properties of the hydrothermally synthesised powder were evaluated with respect to the degradation of methylene blue (BM). Furthermore, the photocatalyst's stability is excellent. The article carefully discusses the detailed mechanism of photocatalysis.

Keywords— $(\text{Na}_{0.5}\text{Bi}_{0.5})\text{TiO}_3$, Hydrothermal method, Raman Spectroscopy, Methylene Blue (BM), Photocatalyst.

Investigating the Molecular Behavior of H₂O in Caso 4 -2H₂O Two-Dimensional Nanoscale System

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Abstract— A molecular fluids' behavior and interaction with other materials at the nanoscale is a complex process. Nanoscale fluids behave so differently than macroscale fluids and interact with other materials in unique ways. It is therefore feasible to understand the molecular behavior of H₂O in such two-dimensional nanoscale systems by studying (CaSO₄-2H₂O), commonly known as gypsum. In the present study, spectroscopic measurements on a 2D structure of exfoliated gypsum crystals are carried out by Raman and IR spectroscopy. An array of gypsum flakes with thicknesses ranging from 8nm to 100nm were observed and analyzed for their Raman and IR spectrum. Water molecules stretching modes spectra lines were also measured and observed in nanoscale gypsum flakes and compared with those of bulk crystals. CaSO₄-2H₂O crystals have Raman and infrared bands at 3341 cm⁻¹ resulting from the weak hydrogen bonds between the water molecules. This internal vibration of water molecules together with external vibrations with other atoms are responsible for these bands. There is a shift about 70 cm⁻¹ in peak position of thin flakes with respect to bulk crystal which is a result of difference atomic arrangement from bulk to thin flake in nano scale. An additional peak was observed in Raman spectra around 2910-3137 cm⁻¹ in thin flakes but is missing in bulk crystal. This additional peak is attributed to a combined mode of water internal (stretching mode at 3394cm⁻¹) and external vibrations. In addition to Raman and infra- red analysis of gypsum 2D structure, electrical measurements were conducted to reveal the water molecules transport behavior in such systems. Electrical capacitance of the fabricated device is measured and found to be (0.0686 *10⁻¹²) F, and calculated dielectric constant (ε) is (12.26).

Keywords—Gypsum, Infra-red spectroscopy, Raman spectroscopy.

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Multiplicative functions with sum zero

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Abstract

CMO functions are completely multiplicative arithmetic functions with sum zero. This function class was initially introduced and investigated by Kahane and Saiás [5]. The main purpose of this paper is to generalise these to multiplicative functions and we shall call them *MO* functions. More precisely, we define such functions to be multiplicative functions for which $\sum_{n=1}^{\infty} f(n) = 0$ and $\sum_{k=0}^{\infty} f(p^k) \neq 0$ for all $p \in \mathbb{P}$. We give some properties and find examples of *MO* functions, as well as pointing out the connection between these functions and the Riemann hypothesis at the end of the paper.

2010 AMS Mathematics Subject Classification: 11N64, 11M41, 11N99

Keywords and phrases: Multiplicative functions, Riemann Hypothesis

1 Introduction

An arithmetical function $f : \mathbb{N} \rightarrow \mathbb{C}$ is called *multiplicative* if $f(1) = 1$ and it satisfies $f(mn) = f(m)f(n)$ whenever $(m, n) = 1$. We define *Möbius function* to be the function given by

$$\mu(n) = \begin{cases} 1 & \text{if } n = 1, \\ (-1)^k & \text{if } n = p_{i_1}p_{i_2} \cdots p_{i_k} \text{ are distinct primes,} \\ 0 & \text{otherwise,} \end{cases}$$

or equivalently, the multiplicative function defined by $\mu(p) = -1$ and $\mu(p^k) = 0$ if $k > 1$ for all primes p . The partial sum of $\mu(n)$ function not exceeding x can be defined by

$$M(x) := \sum_{n \leq x} \mu(n)$$

Several asymptotic formulas have been studied to be equivalent to the PNT by some scholars. For example, H. von Mangoldt 1897 [9] proved that knowing the PNT, it is easy to obtain $\sum_{n=1}^{\infty} \frac{\mu(n)}{n} = 0$ with same elementary steps. However, E. Landau 1909 showed in [7] the converse of von Mangoldt's result also holds. Another equivalent of the PNT, attributed to E. Landau [8], by $M(x) = o(x)$.

In 1912, J. E. Littlewood showed in [6] that the Riemann hypothesis (RH) is equivalent to the following evaluation

$$M(x) = \sum_{n \leq x} \mu(n) = O(x^{\frac{1}{2} + \varepsilon}) \quad \text{for all } \varepsilon > 0. \quad (1)$$

This result have been improved by some scholars (see [7], [15] and [10]). K. Soundararajan 2009 [12] later improved it to be

$$O\left(x^{\frac{1}{2}} \exp\left((\log x)^{\frac{1}{2}} (\log \log x)^{14}\right)\right). \quad (2)$$

M. Balazard and A. de Roton [2] have slightly improved this bound by using a similar approach as K. Soundararajan. They replaced 14 by $\frac{5}{2} + \varepsilon$ in (2). The best possible bound was conjectured by S. M. Gonek (see N. Ng [11]) to be

$$M(x) = O\left(x^{\frac{1}{2}} (\log \log \log x)^{\frac{5}{4}}\right).$$

That is, conjecturally, one cannot get $M(x)$ to be $o\left(x^{\frac{1}{2}} (\log \log \log x)^{\frac{5}{4}}\right)$.

It is also well-known that $M(x)$ are $\Omega(\sqrt{x})$ since there are zeros of the Riemann zeta function ζ on the line $\Re s = \frac{1}{2}$ (see for example [14]).

2 CMO functions

In this section, we introduce a class of functions which has been defined and studied by J.-P. Kahane and E. Saias [5], called *CMO* functions. These are completely multiplicative f for which $\sum_{n=1}^{\infty} f(n) = 0$; *i.e.*

$$f(mn) = f(m)f(n) \quad \text{whenever } (m, n) = 1 \quad \text{and} \quad \sum_{n=1}^{\infty} f(n) = 0.$$

One of their aims was to find and give necessary and/or sufficient conditions on $f(p)$ for f being a *CMO* function. They also provided some examples of these functions. For instance, they discussed various examples of *CMO* functions including $f(n) = \frac{\lambda(n)}{n}$, where $\lambda(n)$ is the Liouville function and $f(n) = \frac{\chi(n)}{n^\alpha}$, where χ is a non-principal Dirichlet character and α is a zero of L_χ with $\Re \alpha > 0$.

This study drove them to think the question of how quickly partial sums of *CMO* functions can tend to zero. They proposed that it is always $\Omega(\frac{1}{\sqrt{x}})$ and the Generalised Riemann Hypothesis - Riemann Hypothesis (GRH-RH) would follow if their suggestion is true. This is because if GRH-RH is false then there is α which is a zero of L_χ with $\Re\alpha > \frac{1}{2}$ which means $\sum_{n \leq x} \frac{\chi(n)}{n^\alpha}$ is not $\Omega(\frac{1}{\sqrt{x}})$. This suggestion is incredibly difficult to prove, but it might be easier to disprove; *i.e.*, to find examples such that

$$\sum_{n \leq x} f(n) = O\left(\frac{1}{x^c}\right) \text{ for some } c > \frac{1}{2}. \quad (3)$$

They did not find any, so in order to find example for which (3) is true we try to look for examples in the generalisation of *CMO* functions.

3 *MO* functions

In this section, we introduce new functions which are a natural generalisation of *CMO* functions. We extend the notion of *CMO* to multiplicative functions and shall call them *MO* functions. We would like to see how much the theory of *CMO* functions can be generalised here. To help motivate our enquiries we consider examples of such functions and properties thereof. For example, let f be a *MO* function and g a multiplicative function “close” to f . We shall show that g is also an *MO* function under some extra condition on f . We can also ask a similar question of Kahane and Saias how quickly the partial sum of *MO* functions up to and including x ; (*i.e.* $\sum_{n \leq x} f(n)$) can tend to zero. We define these functions as follows:

Definition 1 *An arithmetical function $f : \mathbb{N} \rightarrow \mathbb{C}$ is called an *MO* function if it is multiplicative and satisfies*

$$(i) \sum_{n=1}^{\infty} f(n) = 0 \quad \text{and} \quad (ii) \sum_{k=0}^{\infty} f(p^k) \neq 0 \text{ for all } p \in \mathbb{P}.$$

The extra condition (ii) says the series converges but not to zero. This is needed to avoid trivial examples. For instance, let $f(1) = 1$, $f(2) = -1$ and $f(n) = 0$ for all $n > 2$. Then $\sum_{n=1}^{\infty} f(n) = 0$ but $\sum_{k=1}^{\infty} f(2^k) = f(1) + f(2) + f(4) + \dots = 0$, and so does not satisfy the extra condition.

3.1 Examples

Like *CMO* functions which have been studied by Kahane and Saias [5], *MO* functions are not so easy to find since these need to be conditionally convergent (as we

shall see in Proposition 7). To help the readers understanding we give three examples of MO functions. The first is based on the Möbius function, the second on the Dirichlet eta function, which corresponds to the case $k = 2$ in the third example.

Example 2 The function $\frac{\mu(n)}{n}$ is an MO function since:

- (i) it is clear that $\frac{\mu(n)}{n}$ is a multiplicative function;
- (ii) it is well-known that $\sum_{n=1}^{\infty} \frac{\mu(n)}{n} = 0$ (see for example [1]);
- (iii) $\sum_{k=0}^{\infty} \frac{\mu(p^k)}{p^k} = 1 - \frac{1}{p} \neq 0$ for all $p \in \mathbb{P}$.

Example 3 Consider $\frac{(-1)^{n-1}}{n^\alpha}$ which is multiplicative. For which values of $\alpha \in \mathbb{C}$ with $\Re\alpha > 0$ is this an MO function?

- (i) The series $\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n^\alpha}$ converges for $\Re\alpha > 0$ since $A(x) := \sum_{n \leq x} (-1)^{n-1} = O(1)$. Therefore, $0 \leq A(x) \leq 1$ and using Abel summation, we have

$$\begin{aligned} \sum_{n \leq x} \frac{(-1)^{n-1}}{n^\alpha} &= \frac{A(x)}{x^\alpha} + \alpha \int_1^x \frac{A(t)}{t^{\alpha+1}} dt \\ &= O\left(\frac{1}{x^{\Re\alpha}}\right) + \alpha \int_1^\infty \frac{A(t)}{t^{\alpha+1}} dt - \alpha \int_x^\infty \frac{O(1)}{t^{\alpha+1}} dt = C_\alpha + O\left(\frac{1}{x^{\Re\alpha}}\right), \end{aligned}$$

In particular, $\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n^\alpha}$ converges. Now, for $\Re\alpha > 0$, we have

$$\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n^\alpha} = (1 - 2^{1-\alpha})\zeta(\alpha). \tag{4}$$

This is zero if and only if $2^\alpha = 2$ or $\zeta(\alpha) = 0$ (for $\alpha = 1$, the sum on the left of (4) is not zero).

- (ii) It remains to establish for which values of α that $\sum_{k=0}^{\infty} \frac{(-1)^{p^k-1}}{p^{\alpha k}} \neq 0$ for all $p \in \mathbb{P}$.

If $p = 2$, then

$$\sum_{k=0}^{\infty} \frac{(-1)^{2^k-1}}{2^{k\alpha}} = 1 - \sum_{k=1}^{\infty} \frac{1}{2^{\alpha k}} = \frac{2^\alpha - 2}{2^\alpha - 1}.$$

This is non-zero if and only if $2^\alpha \neq 2$; (i.e. For $\frac{(-1)^{n-1}}{n^\alpha}$ to be MO we therefore need $2^\alpha \neq 2$). Now if $p \geq 3$, then

$$\sum_{k=0}^{\infty} \frac{(-1)^{p^k-1}}{p^{k\alpha}} = \sum_{k=0}^{\infty} \frac{1}{p^{\alpha k}} = \frac{1}{1 - \frac{1}{p^\alpha}}.$$

This is non-zero for any α with $\Re\alpha > 0$.

We see that $\frac{(-1)^{n-1}}{n^\alpha}$ is not an MO function if $2^\alpha = 2$ since (ii) does not hold. Therefore we conclude that $\frac{(-1)^{n-1}}{n^\alpha}$ is an MO function if and only if $\Re\alpha > 0$ and $\zeta(\alpha) = 0$ since (i) and (ii) hold.

Furthermore, if $\zeta(\alpha) = 0$ with $\Re\alpha > 0$, then

$$\sum_{n \leq x} \frac{(-1)^{n-1}}{n^\alpha} = O\left(\frac{1}{x^{\Re\alpha}}\right).$$

This example can be generalised as follows:

Example 4 Define $g_k(n)$ as follows:

$$g_k(n) := \begin{cases} 1 - k & \text{if } k \text{ divides } n, \\ 1 & \text{if } k \text{ does not divide } n. \end{cases}$$

We ask for which positive integer $k > 1$ and α with $\Re\alpha > 0$ is the function $\frac{g_k(n)}{n^\alpha}$ MO? When $k = 2$ we get Example 3.

(i) We wish to find all k for which $g_k(n)$ is a multiplicative function as follows: If $m = n = 1$, then $g_k(m)g_k(n) = g_k(mn)$. Now if k divides mn , then we have four cases as follows: Assume $(m, n) = 1$.

(a) If k divides both n and m , then $(m, n) \neq 1$. Hence we cannot have k dividing both m, n since we need $(m, n) = 1$.

(b) If k does not divide n and k divides m , then $g_k(m)g_k(n) = (1 - k)(1) = 1 - k = g_k(mn)$.

or vice versa

(c) If k does not divide m and k divides n , then $g_k(m)g_k(n) = (1)(1 - k) = 1 - k = g_k(mn)$.

(d) If k does not divide both n and m , then we have two cases:

i. If k is not a prime power; (i.e. $k = p_1^{a_1} \cdot p_2^{a_2} \cdots p_i^{a_i}$, where $i \geq 2$ and $a_i \geq 1$). Then, with $m = p_1^{a_1}$ and $n = p_2^{a_2} \cdots p_i^{a_i}$ such that $(m, n) = 1$, we have $g_k(m)g_k(n) = (1)(1) \neq (1 - k) = g_k(mn)$.

ii. If k is a prime power; (i.e. $k = p^r$). Then at least one of m or n is not a multiple of p while the other is (i.e. p does not divide m , then p^r divides n or p does not divide n , then p^r divides m) and $g_k(m)g_k(n) = (1)(1 - k) = (1 - k) = g_k(mn)$ or $g_k(m)g_k(n) = (1 - k)(1) = (1 - k) = g_k(mn)$.

However, if k does not divide mn , then k does not divide both m and n , and $g_k(m)g_k(n) = (1)(1) = 1 = g_k(mn)$.

Thus $g_k(n)$ is multiplicative function if and only if k is a prime power.

(ii) The series $\sum_{n=1}^{\infty} \frac{g_k(n)}{n^\alpha}$ converges for $\Re\alpha > 0$ since

$$\begin{aligned} A(x) &:= \sum_{n \leq x} g_k(n) = \sum_{m=1}^N \sum_{n=(m-1)k+1}^{mk} g_k(n) + \sum_{n=Nk+1}^x g_k(n) = 0 + \sum_{n=Nk+1}^x g_k(n) \\ &= g_k(Nk+1) + g_k(Nk+2) + \dots + g_k(x), \quad \text{where } N = \left\lfloor \frac{x}{k} \right\rfloor \\ &\leq k-1 = O(1). \end{aligned}$$

Thus $0 \leq A(x) \leq k-1$ and using Abel summation, we have

$$\begin{aligned} \sum_{n \leq x} \frac{g_k(n)}{n^\alpha} &= \frac{A(x)}{x^\alpha} + \alpha \int_1^x \frac{A(t)}{t^{\alpha+1}} dt \\ &= O\left(\frac{1}{x^{\Re\alpha}}\right) + \alpha \int_1^\infty \frac{A(t)}{t^{\alpha+1}} dt - \alpha \int_x^\infty \frac{O(1)}{t^{\alpha+1}} dt \\ &= C_\alpha + O\left(\frac{1}{x^{\Re\alpha}}\right), \end{aligned}$$

where C_α is a constant, as in Example 3. In particular, for $\Re\alpha > 0$, $\sum_{n=1}^{\infty} \frac{g_k(n)}{n^\alpha}$ converges.

Now, for $\Re\alpha > 1$, we have

$$\sum_{n=1}^{\infty} \frac{g_k(n)}{n^\alpha} = \sum_{n=1}^{\infty} \frac{1}{n^\alpha} - \sum_{n=1}^{\infty} \frac{k}{(kn)^\alpha} = (1 - k^{1-\alpha})\zeta(\alpha).$$

Thus $\sum_{n=1}^{\infty} \frac{g_k(n)}{n^\alpha} = C_\alpha = (1 - k^{1-\alpha})\zeta(\alpha)$ for $\Re\alpha > 0$ by analytic continuation.

Also, $\sum_{n=1}^{\infty} \frac{g_k(n)}{n^\alpha} = 0$ if and only if $k^\alpha = k$ or $\zeta(\alpha) = 0$.

(iii) It remains to get all k and α for which $\sum_{m=0}^{\infty} \frac{g_k(p^m)}{p^{m\alpha}} \neq 0$ for all $p \in \mathbb{P}$. Let $k = p_0^r$, p_0 a prime number.

If $p_0 \neq p$, then $g_k(p^m) = 1$ for all $m \geq 0$. Hence

$$\sum_{m=0}^{\infty} \frac{g_k(p^m)}{p^{m\alpha}} = \sum_{m=0}^{\infty} \frac{1}{p^{\alpha m}} = \frac{1}{1 - \frac{1}{p^\alpha}}.$$

This is non-zero for any α with $\Re\alpha > 0$. Now if $p_0 = p$, then

$$\begin{aligned} \sum_{m=0}^{\infty} \frac{g_k(p^m)}{p^{m\alpha}} &= \sum_{m=0}^{r-1} \frac{g_k(p^m)}{p^{\alpha m}} + \sum_{m=r}^{\infty} \frac{g_k(p^m)}{p^{\alpha m}} = \sum_{m=0}^{r-1} \frac{1}{p^{\alpha m}} + (1-k) \sum_{m=r}^{\infty} \frac{1}{p^{\alpha m}} \\ &= \frac{1 - p^{-\alpha r}}{1 - p^{-\alpha}} + (1-k) \frac{1}{p^{\alpha r}} \frac{1}{1 - p^{-\alpha}} = \frac{p^{r\alpha} - k}{p^{(r-1)\alpha}(p^\alpha - 1)} = \frac{k^\alpha - k}{k^\alpha(1 - p^{-\alpha})}. \end{aligned}$$

This is non-zero if and only if $k^\alpha \neq k$; (i.e., For $\frac{g_k(n)}{n^\alpha}$ to be MO we therefore need $k^\alpha \neq k$).

We see that $\frac{g_k(n)}{n^\alpha}$ is not an MO function if $k^\alpha = k$ since (iii) fails. Therefore, we conclude that $\frac{g_k(n)}{n^\alpha}$ is an MO function if and only if k is a prime power, $\Re\alpha > 0$ and $\zeta(\alpha) = 0$ since (i), (ii) and (iii) hold.

Furthermore, if $\zeta(\alpha) = 0$ with $\Re\alpha > 0$, then

$$\sum_{n \leq x} \frac{g_k(n)}{n^\alpha} = O\left(\frac{1}{x^{\Re\alpha}}\right).$$

3.2 Some properties of MO functions

In this section, we establish some preliminary properties of MO functions. We shall first need the following result in the course of our discussion.

Proposition 5 *Let f be a multiplicative function. Then $\sum_{n=1}^\infty |f(n)|$ converges, so that f is absolutely convergent, if and only if $\sum_p \sum_{k=1}^\infty |f(p^k)|$ converges.*

Proof *Trivially, the series $\sum_p \sum_{k=1}^\infty |f(p^k)|$ converges if $\sum_{n=1}^\infty |f(n)|$ converges.*

Now suppose $\sum_p \sum_{k=1}^\infty |f(p^k)|$ converges. It follows that

$$\prod_p \left(1 + \sum_{k=1}^\infty |f(p^k)|\right) = \prod_p \left(\sum_{k=0}^\infty |f(p^k)|\right) \text{ converges.}$$

But the right hand side is at least $\prod_{p \leq x} \left\{ \sum_{k=0}^\infty |f(p^k)| \right\}$. Therefore, by the proof of Theorem 11.6 of [1] for any x , we have

$$\prod_{p \leq x} \left\{ \sum_{k=0}^\infty |f(p^k)| \right\} = \sum_{\substack{n \in \mathbb{N} \\ p|n \ \& \ p \leq x}} |f(n)| \geq \sum_{n \leq x} |f(n)|.$$

Hence $\sum_{n=1}^\infty |f(n)|$ converges, so that f is absolutely convergent.

□

Proposition 6 *If f is a CMO function, then f is an MO function; (i.e $CMO \subset MO$).*

Proof *It is clear that f is multiplicative and $\sum_{n=1}^\infty f(n) = 0$. It remains to show that $\sum_{k=0}^\infty f(p^k) \neq 0$ for all $p \in \mathbb{P}$. Now since f is completely multiplicative, then $f(p^k) = f(p)^k$. Therefore*

$$\sum_{k=0}^\infty f(p^k) = \sum_{k=0}^\infty f(p)^k = \frac{1}{1 - f(p)} \neq 0.$$

This series converges since $|f(p)| < 1$. Hence, by Definition 1, f is an MO function. □

Proposition 7 *Let f be an MO function. Then $\sum_{n=1}^{\infty} |f(n)|$ diverges. Indeed $\sum_p \sum_{k=1}^{\infty} |f(p^k)|$ diverges.*

Proof *Let us assume that the statement is false, so that*

$$\sum_{n=1}^{\infty} |f(n)| \text{ converges.}$$

Then, by multiplicative property,

$$\sum_{n=1}^{\infty} f(n) = \prod_p \sum_{k=0}^{\infty} f(p^k) \neq 0 \text{ since } \sum_{k=0}^{\infty} f(p^k) \neq 0.$$

Yielding a contradiction since f is an MO function and hence

$$\sum_{n=1}^{\infty} |f(n)| \text{ diverges.}$$

Furthermore, Proposition 5 gives $\sum_p \sum_{k=1}^{\infty} |f(p^k)|$ diverges, as required. □

3.2.1 Partial sums of MO functions

We know that the partial sum of an MO function not exceeding x tends to zero when x tends to infinity. A question raised by Kahane and Saias [5] regarding CMO functions is: can one show, given $g(x)$, that there exist a CMO function f with

$$\sum_{n \leq x} f(n) = \Omega(g(x))?$$

We are not considering this question, but we are interested in a related question which is: how small can we make $g(x)$, so that the above is true for all MO functions f ? This question motivates the following propositions:

Proposition 8 *If f is an MO function, then*

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x \log x}\right).$$

Proof Let us assume that the statement is false, so that

$$\sum_{n \leq x} f(n) = O\left(\frac{1}{x \log x}\right).$$

We know that for $n \in \mathbb{N}$,

$$f(n) = \sum_{m \leq n} f(m) - \sum_{m < n} f(m) = O\left(\frac{1}{n \log n}\right).$$

Hence

$$f(p^k) = O\left(\frac{1}{p^k \log p^k}\right).$$

Now it follows that $\sum_p \sum_{k=1}^{\infty} |f(p^k)|$ converges since

$$\begin{aligned} \sum_p \sum_{k=1}^{\infty} \frac{1}{p^k \log p^k} &\leq \sum_p \sum_{k=1}^{\infty} \frac{1}{p^k \log p} \quad (\text{since } \log p^k \geq \log p) \\ &= \sum_p \frac{1}{\log p} \sum_{k=1}^{\infty} \frac{1}{p^k} \\ &= \sum_p \frac{1}{(p-1) \log p} \quad \text{converges (since } p_n \log p_n \sim n(\log n)^2). \end{aligned}$$

Thus

$$\sum_p \sum_{k=1}^{\infty} \frac{1}{p^k \log p^k} \text{ converges.}$$

Hence, by Proposition 5, $\sum_{n=1}^{\infty} |f(n)|$ converges. However, by Proposition 7, we have a contradiction, and so it follows that

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x \log x}\right).$$

□

Remark 9 Similarly, if f is an MO function, then

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x(\log x)^\varepsilon}\right) \quad \text{for all } \varepsilon > 0.$$

We can improve Proposition 8 using the fact that $\sum_p \frac{1}{p(\log \log p)^2}$ converges.

Proposition 10 If f is an MO function, then

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x(\log \log x)^2}\right).$$

Proof Let us assume that the statement is false, so that

$$\sum_{n \leq x} f(n) = O\left(\frac{1}{x(\log \log x)^2}\right).$$

We know that for $n \in \mathbb{N}$,

$$f(n) = \sum_{m \leq n} f(m) - \sum_{m < n} f(m) = O\left(\frac{1}{n(\log \log n)^2}\right).$$

Hence

$$f(p^k) = O\left(\frac{1}{p^k(\log \log p^k)^2}\right).$$

Now it follows that $\sum_p \sum_{k=1}^{\infty} |f(p^k)|$ converges since

$$\begin{aligned} \sum_{p \geq 3} \sum_{k=1}^{\infty} \frac{1}{p^k(\log \log p^k)^2} &\leq \sum_{p \geq 3} \sum_{k=1}^{\infty} \frac{1}{p^k(\log \log p)^2} \quad (\text{since } (\log \log p^k)^2 \geq (\log \log p)^2) \\ &= \sum_{p \geq 3} \frac{1}{(\log \log p)^2} \sum_{k=1}^{\infty} \frac{1}{p^k} \\ &= \sum_{p \geq 3} \frac{1}{(p-1)(\log \log p)^2} \text{ converges (since } (\log \log p_n)^2 \sim (\log \log n)^2). \end{aligned}$$

For $p = 2$,

$$\sum_{k=1}^{\infty} \frac{1}{2^k(\log \log 2^k)^2} \leq \frac{1}{2(\log \log 2)^2} + \frac{1}{(\log \log 4)^2} \sum_{k \geq 2} \frac{1}{2^k} \text{ converges.}$$

Thus

$$\sum_p \sum_{k=1}^{\infty} \frac{1}{p^k(\log \log p^k)^2} \text{ converges.}$$

Hence, by Proposition 5, $\sum_{n=1}^{\infty} |f(n)|$ converges. However, by Proposition 7, we have a contradiction, and so it follows that

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x(\log \log x)^2}\right).$$

□

Remark 11 Similarly, if f is an MO function, then

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x(\log \log x)^{1+\varepsilon}}\right) \text{ for all } \varepsilon > 0. \quad (5)$$

Kahane and Saïas [5] have shown that if f is a CMO function, then

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x}\right)$$

by using a deep result of D. Koukoulopoulos in [4]. We attempted to improve (5) to $\Omega(\frac{1}{x})$ as with the work of Kahane and Saïas, but the question is still open.

3.2.2 Closeness relation between two multiplicative functions

Let $\mathcal{M} := \{f : \mathbb{N} \rightarrow \mathbb{C} \text{ multiplicative}\}$, and let us define an (*extended*) *metric* on \mathcal{M} to be the distance function

$$D(f, g) := \sum_p \sum_{k=0}^{\infty} |g(p^k) - f(p^k)|.$$

Then \mathcal{M} is an *extended metric space* since $D(f, g)$ can attain the value ∞ . It is straightforward to check for all $f, g, h \in \mathcal{M}$

- (i) $D(f, g) = 0$ if and only if $f = g$,
- (ii) $D(f, g) = D(g, f)$,
- (iii) $D(f, h) \leq D(f, g) + D(g, h)$,

hold. We aim to extend Theorem 3 of Kahane and Saïas in [5] by showing that if f is an *MO* function and g is a multiplicative function “close” to f , (*i.e.* g has finite distance from f), then g is also an *MO* function. We can do this under an extra condition on f , as the following theorem shows.

Theorem 12 *Let f be an MO function for which*

$$\left| \sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}} \right| \geq a \quad \text{for some } a > 0, \text{ for all } p \text{ and all } \Re s \geq 0, \quad (6)$$

and let g be a multiplicative function such that $D(f, g)$ is finite and

$$\sum_{k=0}^{\infty} g(p^k) \neq 0 \quad \text{for all } p. \quad (7)$$

Then g is an MO function.

Proof *Let $F(s) := \sum_{n=1}^{\infty} \frac{f(n)}{n^s}$ and $G(s) := \sum_{n=1}^{\infty} \frac{g(n)}{n^s}$. Then the series for $F(s)$ is absolutely convergent for $\Re s > 1$ and it is convergent for $\Re s > 0$ and $s = 0$ since $\sum_{n=1}^{\infty} f(n) = 0$. We note that the assumption $D(f, g)$ is finite and the fact that f is an *MO* function imply $|g(p^k)| \rightarrow 0$ as $p^k \rightarrow \infty$. Then, by Theorem 316 of [3], $g(n) \rightarrow 0$ as $n \rightarrow \infty$. Therefore the series for $G(s)$ converges for $\Re s > 1$ since g is bounded. Therefore $F(s)$ and $G(s)$ can be written as follows:*

$$F(s) = \prod_p \sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}} \quad \text{and} \quad G(s) = \prod_p \sum_{k=0}^{\infty} \frac{g(p^k)}{p^{ks}} \quad \Re s > 1.$$

Now

$$H(s) := \prod_p \left(\frac{\sum_{k=0}^{\infty} \frac{g(p^k)}{p^{ks}}}{\sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}}} \right) = \prod_p \left(1 + \frac{\sum_{k=0}^{\infty} \frac{g(p^k) - f(p^k)}{p^{ks}}}{\sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}}} \right)$$

converges absolutely for $\Re s \geq 0$ if and only if

$$\sum_p \frac{\left| \sum_{k=0}^{\infty} \frac{g(p^k) - f(p^k)}{p^{ks}} \right|}{\left| \sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}} \right|} \tag{8}$$

converges for $\Re s \geq 0$. But

$$\sum_p \frac{\left| \sum_{k=0}^{\infty} \frac{g(p^k) - f(p^k)}{p^{ks}} \right|}{\left| \sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}} \right|} \leq \frac{1}{a} \sum_p \sum_{k=0}^{\infty} |g(p^k) - f(p^k)|$$

by (6) so, since $D(f, g)$ is finite, (8) converges for $\Re s \geq 0$ and $H(s)$ converges absolutely to holomorphic function for $\Re s > 0$. However, $H(s) = (G/F)(s)$ for $\Re s > 1$ then $G(s) = F(s)H(s)$, where the series for $F(s)$ converges for $\Re s > 0$ and $s = 0$ since f is an MO function, and $H(s)$ converges absolutely for $\Re s \geq 0$. Therefore $G(s)$ converges for $\Re s > 0$ and $s = 0$ using the extension of Theorem 1.2 of Chapter II.1. [13]. Thus we have $G(0) = F(0)H(0) = 0$. Hence, by assumption (7) and $G(0) = 0$, g is an MO function. □

The proof of Theorem 12 also gives the following result.

Corollary 13 *Let f and g both be multiplicative functions such that $D(f, g)$ is finite and satisfies*

$$\left| \sum_{k=0}^{\infty} \frac{f(p^k)}{p^{ks}} \right| \geq a \quad \text{for some } a > 0 \text{ and all } \Re s \geq 0,$$

$$\left| \sum_{k=0}^{\infty} \frac{g(p^k)}{p^{ks}} \right| \geq b \quad \text{for some } b > 0 \text{ and all } \Re s \geq 0.$$

Then the following two assertions are equivalent:

$$\sum_{n=1}^{\infty} f(n) = 0 \quad \text{and} \quad \sum_{n=1}^{\infty} g(n) = 0.$$

3.3 Open problems

(i) Let f be an MO function. Can we show that

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{x}\right) ?$$

(ii) As pointed out earlier Kahane and Saias suggested that for all CMO functions, one has $\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{\sqrt{x}}\right)$. As also mentioned, GRH-RH (Generalised Riemann Hypothesis-Riemann Hypothesis) would follow if their suggestion is correct.

In Example 2, it is known that $\sum_{n \leq x} \mu(n) = \Omega(\sqrt{x})$ since there are zeros of the Riemann zeta function ζ on the line $\Re s = \frac{1}{2}$ (see [13]). Thus, by Abel summation,

$$\sum_{n \leq x} \frac{\mu(n)}{n} = \Omega\left(\frac{1}{\sqrt{x}}\right).$$

However, for $\sum_{n \leq x} \frac{(-1)^{n-1}}{n^\alpha}$ and $\sum_{n \leq x} \frac{g_k(n)}{n^\alpha}$ to converge to zero in Examples 3 and 4, it is necessary that α be a zero of $\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n^s}$ and $\sum_{n=1}^{\infty} \frac{g_k(n)}{n^s}$ with $\Re \alpha > 0$; (*i.e.* $\zeta(\alpha) = 0$). Suppose this is the case. We then have

$$\sum_{n \leq x} \frac{(-1)^{n-1}}{n^\alpha} = O\left(\frac{1}{x^{\Re \alpha}}\right) \text{ and } \sum_{n \leq x} \frac{g_k(n)}{n^\alpha} = O\left(\frac{1}{x^{\Re \alpha}}\right),$$

and

$$\sum_{n \leq x} \frac{(-1)^{n-1}}{n^\alpha} = \Omega\left(\frac{1}{x^{\Re \alpha}}\right) \text{ and } \sum_{n \leq x} \frac{g_k(n)}{n^\alpha} = \Omega\left(\frac{1}{x^{\Re \alpha}}\right).$$

In our results, we have not found any examples with $\sum_{n \leq x} f(n) = O\left(\frac{1}{x^c}\right)$ for $c > \frac{1}{2}$. This may suggest the following conjecture.

Conjecture 14 *For all MO functions f , we have*

$$\sum_{n \leq x} f(n) = \Omega\left(\frac{1}{\sqrt{x}}\right).$$

Furthermore, the RH would follow if Conjecture 14 were true since if RH is false then there is α which is a zero of ζ with $\Re \alpha > \frac{1}{2}$ which means $\sum_{n \leq x} \frac{(-1)^{n-1}}{n^\alpha}$ and $\sum_{n \leq x} \frac{g_k(n)}{n^\alpha}$ is not $\Omega\left(\frac{1}{\sqrt{x}}\right)$. Therefore, the result of this paper can be considered a new approach to attack the RH.

References

- [1] T. M. Apostol, *Introduction to Analytic Number Theory*, Springer, 1976.
- [2] M. Balazard and A. D. Roton. Notes de lecture de l'article Partial sums of the Mobius function de Kannan Soundararajan, arXiv preprint arXiv:0810.3587, 2008.
- [3] G. H. Hardy and E. M. Wrigh, *An introduction to the theory of numbers*, Oxford university press, 1979.
- [4] D. Koukoulopoulos, On multiplicative functions which are small on average, *Geometric and Functional Analysis*, **23**(5):1569-1630, 2013.
- [5] J.-P. Kahane and E. Saias, Fonctions complètement multiplicatives de somme nulle, *Expositiones Mathematicae*, **35**(4):364-389, 2017.
- [6] J. E. Littlewood, Quelques consequences de l'hypothese que la fonction $\zeta(s)$ de Riemann n'a pas de zeros dans le demi-plan $\text{Re } s > 1/2$, *CRAS Paris*, 154:263-266, 1912.
- [7] E. Landau, Uber die mobiusche funktion. *Rendiconti del Circolo Matematico di Palermo* (1884-1940), 48(2):277-280, 1924.
- [8] E. Landau, Neuer beweis der gleichung $\sum_{k=0}^{\infty} \frac{mu(k)}{k}$, PhD thesis, Druck Der Dieterich'schen Univ.-Buchdruckerei (W. Fr. Kastner), 1899.
- [9] H. von Mangoldt, Beweis der gleichung $\sum_{k=0}^{\infty} \frac{mu(k)}{k}$, *Proc. Royal Pruss. Acad. of Sci. of Berlin*, pages 835-852, 1897.
- [10] H. Maier and H. L. Montgomery, The sum of the Mobius function. *Bulletin of the London Mathematical Society*, 41(2):213-226, 2009.
- [11] N. Ng, The distribution of the summatory function of the Mobius function. *Proceedings of the London Mathematical Society*, 89(2):361-389, 2004.
- [12] K. Soundararajan, Partial sums of the Mobius function. *Journal fur die reine und angewandte Mathematik (Crelles Journal)*, 361:141-152, 2009.
- [13] G. Tenenbaum, *Introduction to analytic and probabilistic number theory*, volume 163. American Mathematical Society, 2015.
- [14] E. C. Titchmarsh and D. R Heath-Brown, *The theory of the Riemann zeta-function*, Oxford University Press, 1986.
- [15] E. C. Titchmarsh, A consequence of the Riemann Hypothesis, *Journal of the London Mathematical Society*, 1(4):24-254, 1927.

Malfatti's Problem in a Reuleaux Triangle

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Abstract

Malfatti's Problem is to ask for fitting three circles into a right triangle such that they are tangent to each other, and each circle is also tangent to a pair of the triangle's side. This problem has been extended to any triangle (called general Malfatti's Problem). Furthermore, the problem has been extended to have $1+2+\dots+n$ circles, we call it the extended general Malfatti's problem, these circles are identified as corner circles which tangent to two circles and two sides of the triangle, boundary circles which tangents to four circles and one sides of the triangle, and inner circles which tangent to six other circles. In the extended general Malfatti's problem, there are closed-form solutions for $n=1, 2$, and the problem becomes complex when n is greater than 2. In solving the extended general Malfatti's problem ($n>2$), we initially give values to the radii of all circles. From the tangency graph and current radii, we can compute the angle value between two vectors. These vectors are from the center of the circle to the tangency points with surrounding elements, and these surrounding elements can be the boundary of the triangle or other circles. For each circle C , there are vectors from its center c to its tangency point with its neighbors (count clockwise) $p_i, i=0, 1, 2, \dots, n$. We add all angles between cp_i to $cp_{(i+1) \bmod (n+1)}, i=0, 1, \dots, n$, call it $\text{sumangle}(C)$ for circle C . Using $\text{sumangle}(C)$, we can reduce/enlarge the radii for all circles in the next iteration, until $\text{sumangle}(C)$ is equal to 2π for all circles. With a similar idea, this paper proposed an algorithm to find the radii of circles whose tangency has the structure of Pascal's triangle, and the exterior circles of these circles tangent to unit Reuleaux Triangle.

Keywords: Malfatti's problem, Geometric Constraint Solver, Computer-Aided Geometric Design, Circle Packing, Data Visualization

1. Introduction

In this paper, we aim to solve the Malfatti's problem in a Reuleaux Triangle, and thus, we introduce the Malfatti's Problem and Reuleaux in this section.

1.1 Malfatti's Problem

Given a triangle, we want to find three circles inside the triangle, these circles are tangent to each other, and every circle tangents to two edges of the given triangle - we call this problem the Malfatti's problem. An instance of this problem is shown in Fig. 1 [5].

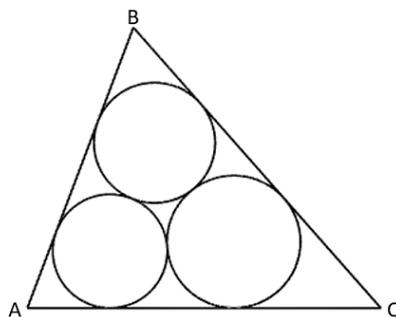


Fig. 1 Malfatti's problem

Since then, this second problem, which Malfatti believed to maximize the area, has become understood to be Malfatti's problem in the literature. There are several known solutions of Malfatti's problem. Fukagawa and Pedoe [1] mentioned that the general Malfatti's problem on an arbitrary triangle was actually formulated and solved by Chokuen Ajima. The interested reader is referred to [2]-[4] for a history of the problem and an explanation of various solutions and generalizations.

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The general Malfatti problem is the problem to find three circles in an arbitrary triangle, these circles tangent to each other externally, and each circle tangents to two sides of the triangle. We want to extend the problem to $\sum_0^n (i + 1)$, $n=0, 1, 2, \dots$ circles inside the triangle, with tangency properties among the circles and edges of the triangles. Consider the number of triangles is $\sum_0^n (i + 1)$, as shown in Fig. 2(a), Fig. 2(b), Fig. 2(c) for the case $n=1, 3, 30$, EGM Layer n problem [5], [6].

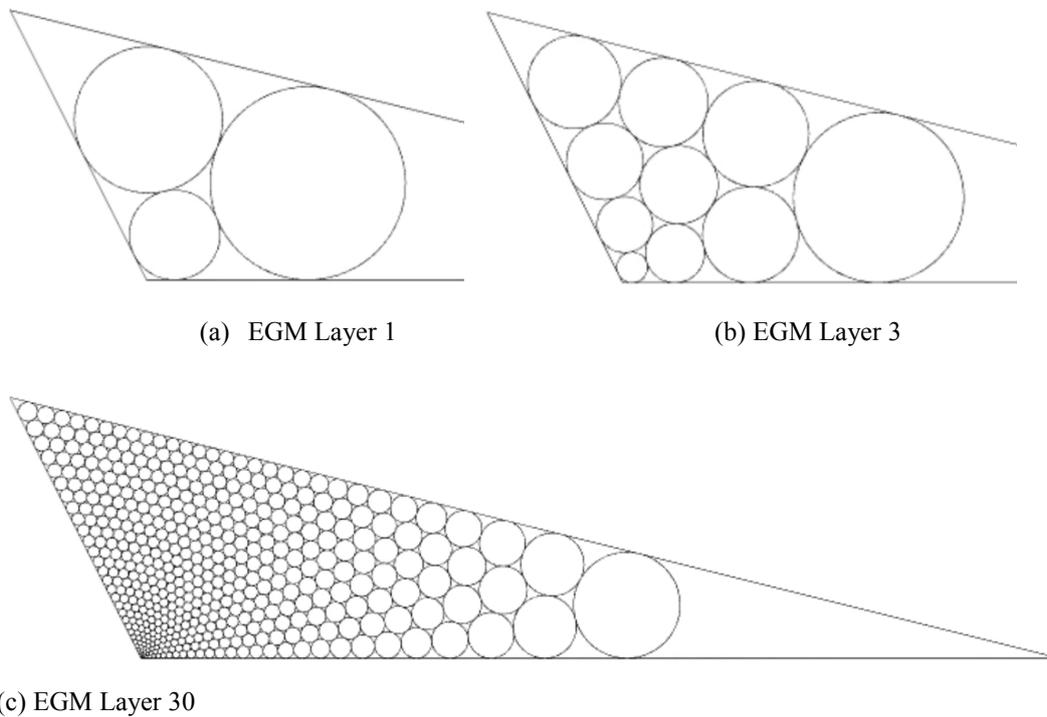


Fig. 2 Extended General Malfatti's (EGM) Problem

1.2 The Reuleaux Triangle.

Consider a right triangle, we use one vertex as a center, the length of the triangle as radius, and draw a 60-degree circular arc connecting the other two vertices, as shown in Fig. 3(a). We call this curved triangle the Reuleaux Triangle (RT). If the edge of the right triangle has length 1, we call this shape the unit Reuleaux Triangle. In this paper, RT always means the unit Reuleaux Triangle.

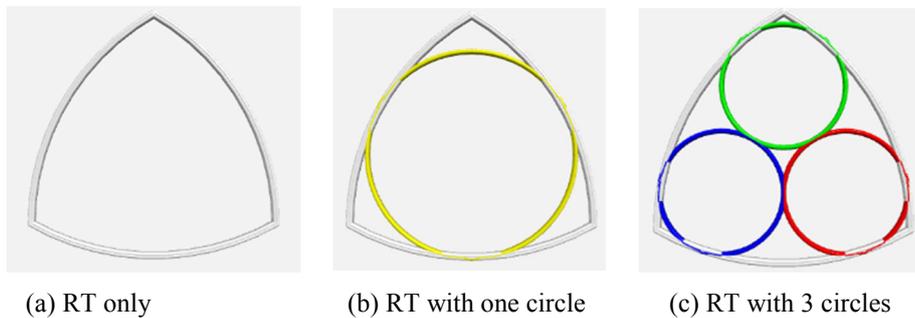


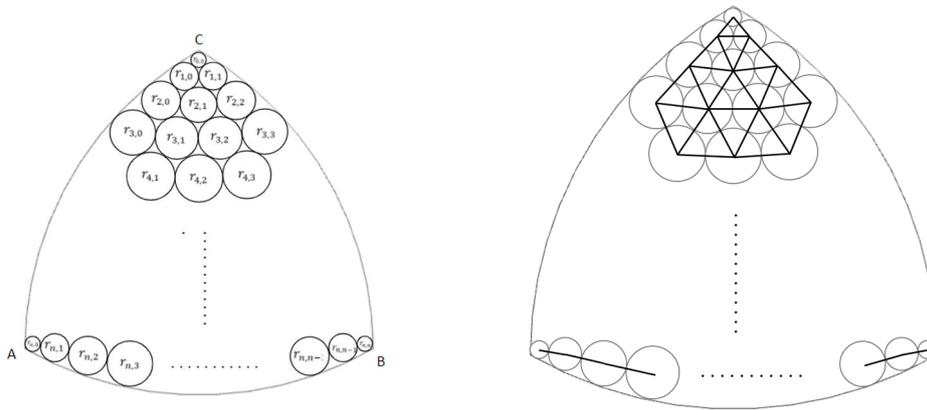
Fig. 3 Reuleaux triangle (RT)

There are six sections in this paper. The first section gives the simple description of Malfatti's problem and Reuleaux triangle. The second section illustrated the problem we want to solve. The third section gives mathematical analysis for simple case in the problem. We proposed an algorithm to solve complex case in the problem. The fifth section gives the example and performance for this problem. Finally, the conclusion is in section six.

2. Problem Statement

The problem we want to solve is to find the radius of $1+2+\dots+(n+1)$ circles inside the RT, so that the circles have the tangency properties with its neighbor six circles (we call this circle inner circle, as the circle with radius $r_{2,1}$ in Fig.4(a)), or one side of RT and four neighbor circles (we call it boundary circle, as the circle with radius $r_{2,0}$ in Fig.4(a)), or two

sides of RT and two neighbors (we call it corner circles, as the circle with radius $r_{0,0}$ in Fig.4(a)). Notice that there are three corner circles, $3(n-1)$ edge circles and $(n-1)(n-2)/2$ inner circles. Totally $(n+1)(n+2)/2$ circles if $n>0$. There are no edge and inner circles if $n=1$. There is only one corner circle if $n=0$. We call this problem RT(n) problem ($n\geq 0$) if the total number of circles is $(n+1)(n+2)/2$.



(a) RT(n) (b) Tangency graph for TT(n)

Fig. 4 The circles inside RT with its tangency graph

Consider the graph whose vertex is the center of all circles, and each edge represents the tangency properties for two circles, we call this graph is a tangency graph for the specified RT(n) figures. Fig. 4(b) is the tangency graph for Fig. 4(a). for the situation in Fig. 4(a), we call this tangency graph (Fig. 4(b)) has the structure as Pascal's Triangle. So, the RT(n) problem is the problem that we want to find circles fit in the RT with its tangency graph has the structure as Pascal's Triangle. The exterior circles of all circles must also tangent to the side (circular arc) of RT.

We want to solve $n=0$ and $n=1$ mathematically, and proposed an algorithm for the generalized problem $n>1$.

3. Mathematical Analysis

We solve the RT(0) and RT(1) problem mathematically in section 3.1, and section 3 describes some theorems used in the proposed algorithm in this paper.

3.1 RT(0) and RT(1) problems

In this paper, we fixed the vertices of the unit Reuleaux triangle at $(\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, $(-\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, $(0, \frac{1}{\sqrt{3}})$. Notice the edge connect any two of these three vertices has unit length and the center of inscribed circle of this triangle is at the origin. For other non-unit RT problems, we can find solution (radii of circles) for unit RT, and shrink/enlarge the radii of circles and RT simultaneously, depending on the ratio of the side length for non-unit RT and the side length for unit RT. So, when we want to find the solution for the non-unit RT, we can always switch the problem from the non-unit RT into unit RT by translation, rotation and scaling transformations, and then find solution for unit RT, and switch back to the original problem by reversing the translation, rotation and scaling transformation process. For RT(0) and RT(1) problem, we have the following theorem:

Theorem 1: Let the unit RT whose vertices are at $(\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, $(-\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, $(0, \frac{1}{\sqrt{3}})$, the circle tangents to the lower edge and right edge of the RT centered at $(X(t), Y(t)) = (\frac{1}{2}(1-t), -\frac{1}{2\sqrt{3}}(1-t))$ with radius $R(t) = 1 - \frac{1}{\sqrt{3}}\sqrt{t^2 - 3t + 3}$. Furthermore, the distance from the right vertex $(\frac{1}{2}, -\frac{1}{2\sqrt{3}})$ to $(X(t), Y(t))$ is equal to $\frac{1}{\sqrt{3}}t$. ($t>0$).

Proof: Consider the parameter equation for the ray point from the right corner of the RT to the origin:

$$L(t) = (X(t), Y(t)) = (1-t)\left(\frac{1}{2}, -\frac{1}{2\sqrt{3}}\right), 0 \leq t \leq 1.$$

For fixed t , the radius function of the circle centered at $(X(t), Y(t))$ and tangents to the right arc and low arc, as shown in Fig. 5, can be calculated by finding $R(t) = 1$ minus the distance from the center $(X(t), Y(t))$ to the left corner of the RT. The distance from $(\frac{1}{2}, -\frac{1}{2\sqrt{3}})$ to $(X(t), Y(t))$ can be easily derived.

Notice that the distance from the right lower vertex to $(X(t), Y(t))$ is $\frac{1}{\sqrt{3}}t$. When $t=0$, $(X(t), Y(t))$ is the right corner, and $R(t)=0$, and when $t=1$, the circle tangent to all three arcs of the RT.

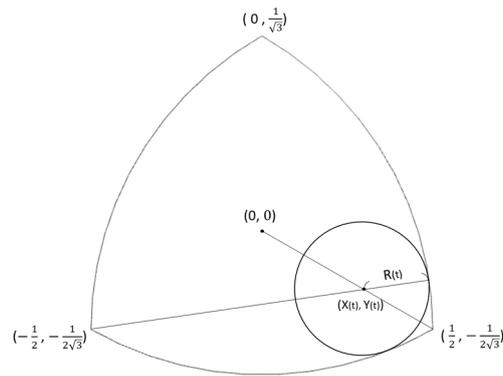


Fig. 5 Radius function for corner circle.

Instead of finding the circle tangent to the lower and right arcs, the circle tangents to the left and right arcs can be also derived by the following corollary:

Corollary 1: Let the unit RT whose vertices are at $(\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, $(-\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, $(0, \frac{1}{\sqrt{3}})$, the circles' tangents to the left and right arcs of the RT centered at $(X(t), Y(t)) = (0, \frac{1}{\sqrt{3}}(1-t))$ with radius $R(t) = 1 - \frac{1}{\sqrt{3}}\sqrt{t^2 - 3t + 3}$. Furthermore, the distance from the upper vertex $(0, \frac{1}{\sqrt{3}})$ to $(X(t), Y(t))$ is equal to $\frac{1}{\sqrt{3}}t$. ($t > 0$).

Notice that the radius functions for Theorem 1 and Corollary 1 are the same.

For the RT(0) problem, we have the following theorem:

Theorem 2: (RT(0) problem): The radius for one Malfatti's circle in unit RT is $1 - \frac{1}{\sqrt{3}}$.

Proof: From theorem 1, when $t=1$, we can find the circle centered at the origin whose radius $1 - \frac{1}{\sqrt{3}}$. This circle tangent to the right and lower arcs. From Corollary 1, we find the same circle tangent to the left and right arcs. So, this circle with radius $1 - \frac{1}{\sqrt{3}}$ is tangent to three arcs of the RT. ✖

For the RT(1) problem, we have the following theorem:

Theorem 3: (RT(1) problem): The radii for three Malfatti's circles in a unit RT are all equal to $3\sqrt{2}-4$.

Proof: From the symmetry property of the unit RT, we know that the three Malfatti's circles have the same radius. Furthermore, the lower left and right circle tangent to the Y-axis. So, consider the equation in theorem 1, we need to add one more constraint, $X(t)=R(t)$. With this equation, $X(t)=R(t)$, we find two solutions $t=9+6\sqrt{2}$ and $9-6\sqrt{2}$. With $0 \leq t \leq 1$, we select $t=9-6\sqrt{2}$, and find $r=X(9-6\sqrt{2})=3\sqrt{2}-4$.

Notice that when we find $t=9-6\sqrt{2}$, it is easy to find the center of these three circles by calculating $Y(t)$, $t=9-6\sqrt{2}$. The right circle centered at $(r, -\frac{1}{\sqrt{3}}r)$, $r=3\sqrt{2}-4$. The left circle centered at $(-r, -\frac{1}{\sqrt{3}}r)$. Calculating the distance from the center of the right circle to the origin, we can find the center of the upper circle is at $(0, \frac{2}{\sqrt{3}}r)$.

3.2 Theorem for the proposed algorithm

The algorithm we proposed is finding the circles inside the RT, so that the circles (corner circles, edge circles and inner circles) satisfied some tangency properties; its tangency graph is shown in Fig. 4(b). For these three different kinds of circles, we calculate all the angles between vectors from a circle's center to a tangency point on the circle, and also on boundary curve of the RT or other circles. Notice that we need to calculate 4, 5 and 6 angles for the corner, boundary, and inner circles, respectively (see Fig. 6(a), Fig. 6(b), and Fig. 6(c)). The sum of the angle for circle C, denote $\text{sumangle}(C)$, which is the sum of these 4, 5, 6 angles for the corner, boundary and inner circles when we specified the radius for each circle in the RT. If $\text{sumangle}(C)$ is greater/less than 2π , we increase/decrease the radius of C. When $\text{sumangle}(C)$ is equal to 2π , we keep the same radius value for radius of C.

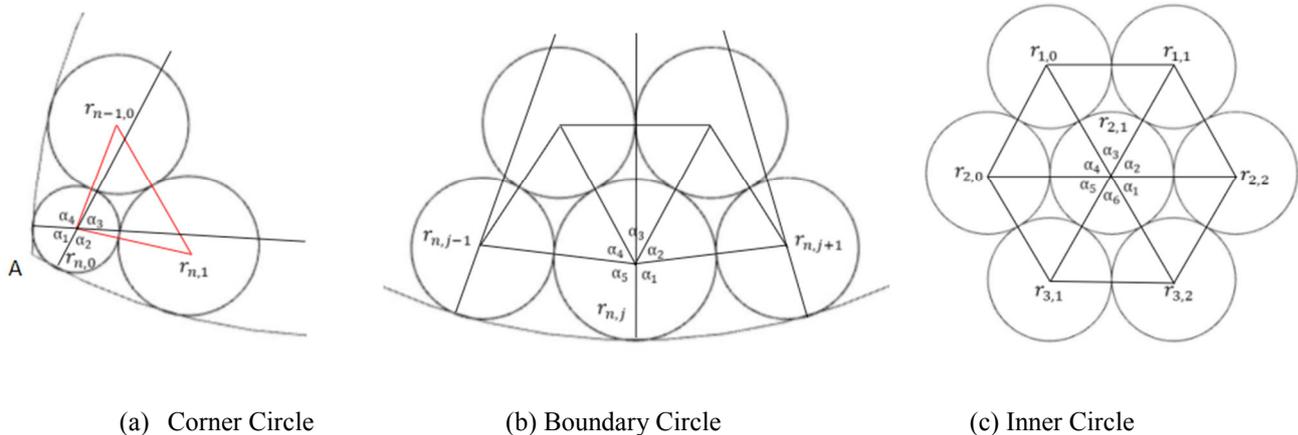


Fig. 6 Sumangle(C) for different circles

Based on the angle between two vectors as in Fig. 6, we classify it into three categories:

These two vectors are both from circle center to tangency point, which is also the other circle's boundary (Fig. 6(a) α_3 ; Fig. 6(b) α_2 to α_4 ; Fig. 6(c) α_1 to α_6). Notice that the six angles for the inner circles is all in this case.

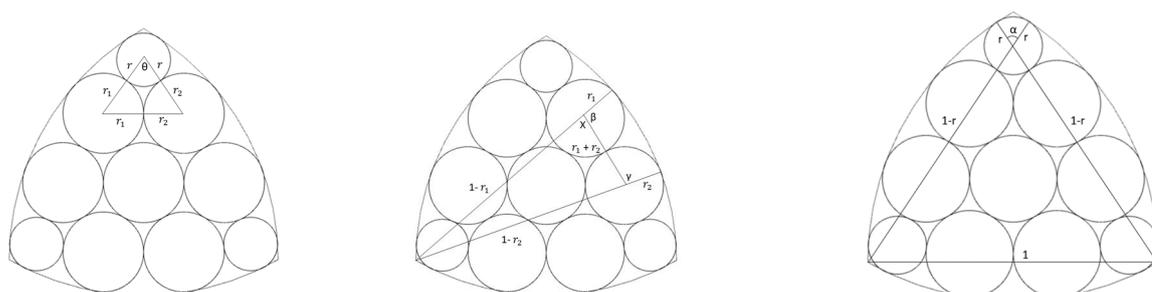
One vector is from the circle center to the other circle's boundary and the other vector is from the circle center to the boundary of the RT. (Fig. 6(a) α_2, α_4 ; Fig. 6(b) α_1, α_5).

These two vectors are from the center of the corner circle to the tangency point on two boundary arcs (Fig. 6(a) α_1). Notice that only the corner circles have this property.

For these three cases, we have the following theorem:

Theorem 4: Let the corner circles have radius r , and the two circles' tangent to have radius r_1 , and r_2 , respectively, as shown in Fig. 7(a). Then the angle $\theta = \frac{r^2 + (r_1 + r_2)r - r_1 r_2}{(r + r_1)(r + r_2)}$.

Proof: From the triangle with side length $r + r_1$, $r + r_2$ and $r_1 + r_2$, as shown in Fig. 7(a), we can find θ using the cosine rule.



(a) To other two circles (b) To one other circle and RT's boundary (c) To two RT's boundary

Fig. 7 The angle calculation.

Theorem 5: Consider two boundary neighbor circles with radii r_1 , and r_2 , as shown in Fig. 7(b), then $\beta = \cos^{-1} \frac{r^2 + (r_1 + r_2)r - r_1 r_2}{r^2 + (r_1 + r_2)r + r_1 r_2}$.

Proof: Consider the triangle with side length $1 - r_1$, $1 - r_2$ and $r_1 + r_2$, we can find the angle χ by cosine rule, and $\beta = \pi - \chi$.

Theorem 6: Consider the corner circles with radius r , as shown in Fig. 7(c), then $\alpha = \cos^{-1} \left(\frac{2r^2 - 4r + 1}{2r^2 - 4r + 2} \right)$

Proof: From the triangle with side length $1 - r$, $1 - r$ and 1 , we can find the angle α using cosine rule.

Currently, we consider whether $\text{Sumangle}(C) = 2\pi$ (within a tolerance) for all circles. If it is, we multiple all radii by a constant c , we enlarge the figure size by c^2 . And, $\text{Sumangle}(C) = 2\pi$ (within a tolerance) for all circles are still satisfied. We need one more constraint so that this group of circles fit in (tangent to) the RT.

When we find a set of circles satisfied the requirement mentioned above ($\text{Sumangle}(C) = 2\pi$ (within a tolerance) for all circles), we want multiple all radii with a ratio, so that this group of circles fit inside of RT and tangent to the boundary of RT. Consider one set of boundary circles, as shown in Fig. 8 as an example, we want to calculate the sum of angles from θ_1 to θ_5 ; if the sum is greater or less than $\pi/3$, we reduce or enlarge the radii for all circles, until the sum of angles is equal to $\pi/3$. After this reduce/enlarge process, we can find one solution for this problem.

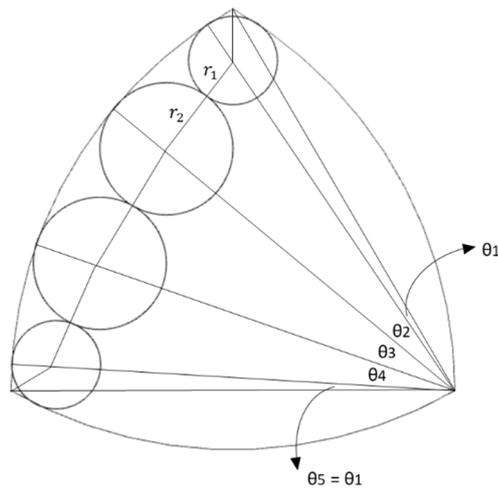


Fig. 8 The constraint to find one solution fit in RT

Notice that θ_2 to θ_4 , can be calculated by cosine rule for the triangle with side length $1-r_1$, $1-r_2$, and r_1+r_2 , and θ_1 (which is equal to θ_5 , because the symmetry property of RT) can be calculated by the triangle side length 1 , $1-r_1$, and the length from circle center to the associated vertex of the RT.

4. Algorithm

We proposed the following algorithm to solve RT(n), $n > 1$ problem.

Algorithm:

1. Input n
2. Given initial radius $r_{i,j} = 1/(n+1)$.
3. While one of $\text{sumangle}(C_{i,j})$ is not equal 2π (within a tolerance)
 - 3.1 Calculate the enlarge/reduce amount for the radius of $C_{i,j}$
(reduce if $\text{sumangle}(C_{i,j}) > 2\pi$; enlarge if $\text{sumangle}(C_{i,j}) < 2\pi$).
 - 3.2 Enlarge/reduce all radii in the same time.
 - 3.3 Enlarge/reduce so that the result figures fit in the RT.
4. Draw the result.

At first (step 1), we input an integer n ($n > 1$), set an initial radius value for all circles (step 2). Then, we use a while loop (step 3) to repeat many iterations until all circles $\text{sumangle} = 2\pi$. Inside the while loop, we compute $\text{sumangle}(C)$ for each circle (step 3.1), and enlarge/reduce radii for all circles simultaneously (step 3.2). After that, we give one more constraint to enlarge/reduce the radii of all circles with one common ratio (step 3.3). After the while loop in step 3, we find the solution for RT(n) problem.

5. Implement and Examples

We use Python 3 to implement the above algorithm in a PC (Intel Core i5-10210U CPU), and test for $RT(n)$, $n=1, 2, 3, 4, 8, 16$, to get the images shown Fig. 9 and the information in Table 1.

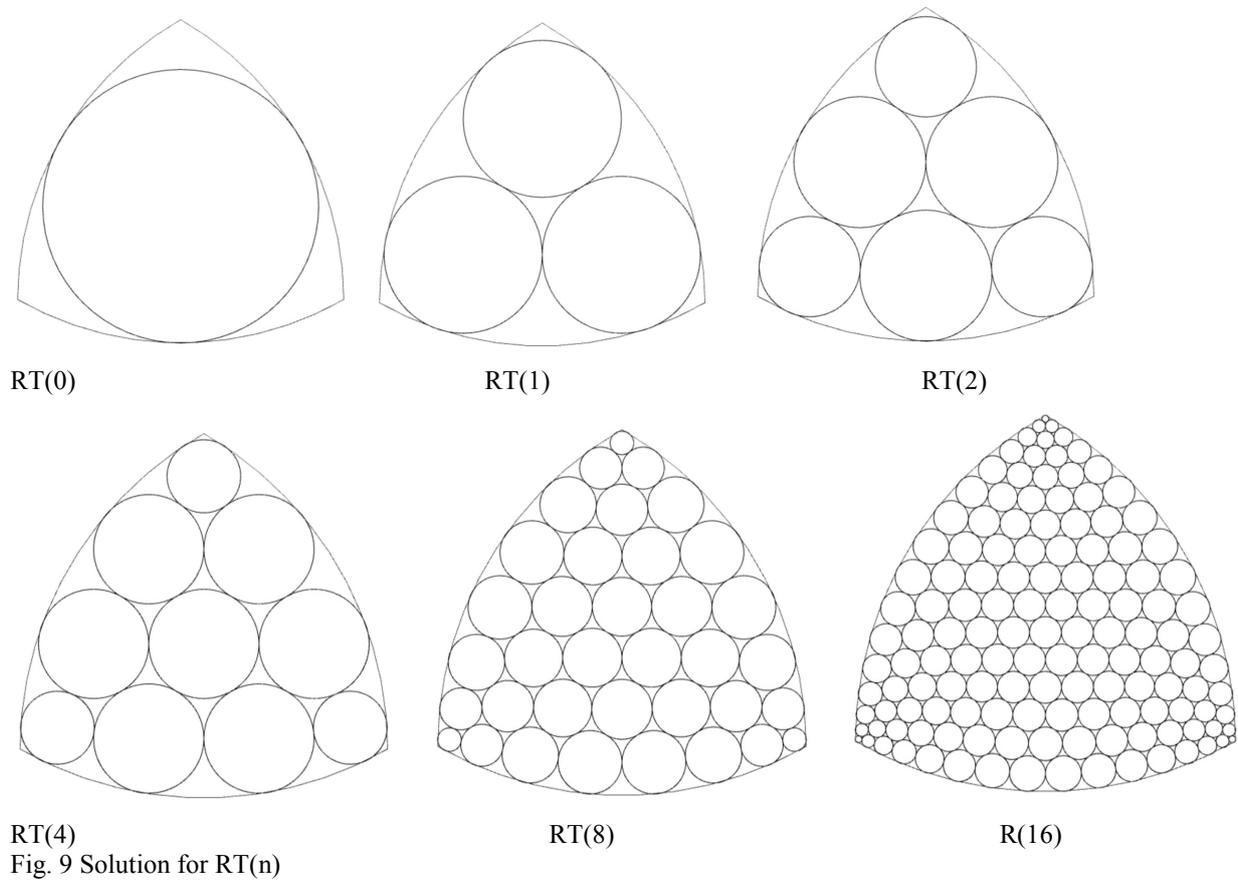


Table 1 The performance for the proposed algorithm

n.	Exec. time	Iterations	Corner circle (radius)	Boundary circle (radius or radius range)	Inner circle (radius or radius range)
0	2.120 s	0	0.42264973081037416	x	x
1	2.137 s	0	0.2426416158052694	x	x
2	2.138 s	16	0.150102838921243	0.19615154745579616	x
3	2.142s	28	0.10009372945506108	0.14982936115233983	0.14982885508162738
7	2.148 s	104	0.0320547586757209	(0.05735748774672348, 0.0866274571765566)	(0.07017399289287517, 0.08188603342975646)
15	2.587 s	363	0.00897401021392445	(0.01703923511580696, 0.04711974247356444)	(0.023091276709598898, 0.04464989885481654)

In Table 1, the first column indicates the value n for the $RT(n)$ problem and the second column is the execution time (seconds) for associated problem. The third column is the number of iteration s in the while loop of the proposed algorithm, and for $n=0$ and $n=1$, we use the formula in Theorem 2 and Theorem 3 directly, so that the number of iterations is 0. We know the $RT(0)$ and $RT(1)$ problem has only corner circles inside, while $RT(2)$ has corner and boundary circles. Starting

from $RT(n)$, $n > 2$, the corner, boundary and inner circles all exist inside the RT . The fourth column to sixth column indicates the radius or radius range of the corner, boundary, inner circle for $RT(n)$, $n=0,1,2,3$, cases. Notice that the radii range for the boundary circle is wider than the radii range for the inner circle in $RT(7)$ and $RT(15)$.

When we find $\text{sumangle}(C)$, we can enlarge/reduce the radius by adding/subtracting the radius with a small constant. However, this approach takes more iterations if we select the improper small constant. We use the ratio $\text{sumangle}(C)/2\pi$ to enlarge/reduce the radii; that is, the new radius $r' = r \times \text{sumangle}(C) / 2\pi$. This approach reduces the number of iterations and improves the performance of the algorithm.

6. Conclusion and Future Research:

The $RT(n)$, $n \geq 0$ problem, can be solved and its figure can be constructed in the proposed algorithm in this paper. Because the symmetry properties of RT , three corner circles should have the same radius. It seems that the range of the radius for the boundary circle is wider than the range of the radius for the inner circle. The CPU time used for $n=0$ to $n=15$ has no much difference. Most of the time used on display the figures.

The extended Malfatti's problem solves the circles problem in triangle, whose boundary is a straight line (degree 1 curve). In this paper, we proposed algorithm to solve the $RT(n)$ problem, and RT has circular arc (degree 2 curve) as its boundary. There are many different types and/or different degrees of boundary curves, such as a Bezier curve, can be further investigated.

REFERENCES

- [1] Fukagawa, H. and Pedoe, D. "The Malfatti Problem." *Japanese Temple Geometry Problems (San Gaku)*. Winnipeg: The Charles Babbage Research Centre, pp. 28 and 103-106, 1989.
- [2] O. Bottema, "The Malfatti Problem," *Forum Geometricorum* 1, 43-50, 2000.
- [3] M. Stefanović. "Triangel centers associated with the Malfatti circles." *Forum Geometricorum* 3, 83-93, 2003.
- [4] Wolfram MathWorld. "Malfatti Circles," <http://mathworld.wolfram.com/MalfattiCircles.html>
- [5] Ching-Shoei Chiang, Christoph M. Hoffmann, Paul Rosen, "A generalized Malfatti's Problem", *Computational Geometry*, Volume 45, Issue 8, October 2012, pages 425-435.
- [6] Ching-Shoei Chiang, Hung Chieh Li, Min-Hsuan Hsiung, and Fan-Ming Chiu, "Extended General Malfatti's Problem, The 19th International Conference on Scientific Computing, 2021/7/26-29.

A Philosophical Investigation into African Conceptions of Personhood in the Fourth Industrial Revolution

Sanelisiwe Ndlovu

Abstract— Cities have become testbeds for automation and experimenting with artificial intelligence (AI) in managing urban services and public spaces. Smart Cities and AI systems are changing most human experiences from health and education to personal relations. For instance, in healthcare, social robots are being implemented as tools to assist patients. Similarly, in education, social robots are being used as tutors or co-learners to promote cognitive and affective outcomes. With that general picture in mind, one can now ask a further question about Smart Cities and artificial agents and their moral standing in the African context of personhood. There has been a wealth of literature on the topic of personhood; however, there is an absence of literature on African personhood in highly automated environments. Personhood in African philosophy is defined by the role one can and should play in the community. However, in today's technologically advanced world, a risk is that machines become more capable of accomplishing tasks that humans would otherwise do. Further, on many African communitarian accounts, personhood and moral standing are associated with active relationality with the community. However, in the Smart City, human closeness is gradually diminishing. For instance, humans already do engage and identify with robotic entities, sometimes even romantically. The primary aim of this study is to investigate how African conceptions of personhood and community interact in a highly automated environment such as Smart Cities. Accordingly, this study lies in presenting a rarely discussed African perspective that emphasizes the necessity and the importance of relationality in handling Smart Cities and AI ethically. Thus, the proposed approach can be seen as the sub-Saharan African contribution to personhood and the growing AI debates, which takes the reality of the interconnectedness of society seriously. And it will also open up new opportunities to tackle old problems and use existing resources to confront new problems in the Fourth Industrial Revolution.

Keywords— smart city, artificial intelligence, personhood, community.

Smart in Performance: More to Practical Life Than Hardware and Software

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Abstract— This paper promotes the importance of focusing on spatial aspects and affective factors that impact smart urbanism. This helps to better inform city governance, spatial planning, and policymaking to focus on what Smart does and what it can achieve for cities in terms of performance rather than on using the notion for prestige in a worldwide trend towards becoming a smart city. By illustrating how this style of practice compromises the social aspects and related elements of space making through an interdisciplinary comparative approach, the paper clarifies the impact of this compromise on the overall smart city performance. In response, this paper recognizes the importance of establishing a new meaning for urban progress by moving beyond improving basic services of the city to enhance the actual human experience which is essential for the development of authentic smart cities. The topic is presented under five overlooked areas that discuss the relation between smart cities' potential and efficiency paradox, the social aspect, connectedness with nature, the human factor, and untapped resources. However, these themes are not meant to be discussed in silos, instead, they are presented to collectively examine smart cities in performance, arguing there is more to the practical life of smart cities than software and hardware inventions. The study is based on a case study approach, presenting Milton Keynes as a living example to learn from while engaging with various methods for data collection including multi-disciplinary semi-structured interviews, field observations, and data mining.

Keywords— smart design, the human in the city, human needs and urban planning, sustainability, smart cities, Smart

REFERENCES

- [1] Aldridge, J., 2019, Thames Valley Police rated 'inadequate' as inspectors say they're failing victims. <https://www.getreading.co.uk/news/reading-berkshire-news/thames-valley-police-rated-inadequate-16648739>
- [2] Browning, W.D., Ryan, C.O. and Clancy, J.O., 2014. 14. Patterns of biophilic design. New York: Terrapin Bright Green, LLC..
- [3] Downton, P., Jones, D., Zeunert, J. and Roos, P., 2017, January. Biophilic design applications: theory and patterns into built environment education. In DesTech 2016: Proceedings of the International Conference on Design and Technology (pp. 59-65). Knowledge E.
- [4] Healey, P., 2007. Urban complexity and spatial strategies: Towards a relational planning for our times. Routledge.
- [5] Heerwagen, J. and Heerwagen, J.H., 2017. Psychosocial value of space. Whole Building Design Guide.
- [6] <https://www.stophateuk.org/about-hate-crime/racism-in-the-uk/>, Accessed 01 Mar 2022.
- [7] <https://www.victimsupport.org.uk/more-us/about-us/>, Accessed 01 Mar 2022.
- [8] Karvonen, A., 2020. Urban Techno-Politics: Knowing, Governing, and Imagining the City. *Science as Culture*, 29(3), pp.417-424.
- [9] Kellert, S.R., Heerwagen, J. and Mador, M., 2011. *Biophilic design: the theory, science and practise of bringing buildings to life*. John Wiley & Sons.
- [10] Muñoz-Erickson, T.A., Miller, C.A. and Miller, T.R., 2017. How cities think: knowledge co-production for urban sustainability and resilience. *Forests*, 8(6), p.203.
- [11] Oppong, T., 2020. Psychologists Explain How Emotions, Not logic, Drive Human Behavior Medium. URL <https://medium.com/personal-growth/psychologists-explain-how-emotions-not-logic-drive-human-behaviour-6ed0daf76e1a> (accessed 2.4.21).
- [12] Pallasmaa, J., 2014. Space, place and atmosphere. Emotion and peripheral perception in architectural experience. *Lebenswelt. Aesthetics and philosophy of experience.*, (4).
- [13] Pallasmaa, J., 2017. *Architecture as Experience: Human Perception and the Built Environment Symposium*, Richard H. Driehaus Foundation 2017, Chicago, 30th September, 2017.
- [14] Pallasmaa, J., 1995. *The Eyes of the Skin: Architecture and the Senses*. John Wiley & Sons.
- [15] Pallasmaa, J., 2009. *The Thinking Hand. AD Primer*, London.
- [16] Pallasmaa, J., 2011. *The Embodied Image. Imagination and Imagery in Architecture*. Italia: Editorial Wiley.
- [17] Pallasmaa, J., Pallasmaa, Holl & Pérez-Gómez, S. and Pérez-Gómez, A., 1994. *Questions of Perception: Phenomenology of Architecture*.
- [18] Richardson, M. and Butler, C.W., 2022. Nature connectedness and biophilic design. *Building Research & Information*, 50(1-2), pp.36-42.
- [19] Sarkar, A.N., 2017, *Smart Cities: A Futuristic Vision*, <https://www.thesmartcityjournal.com/en/articles/1333-smart-cities-futuristic-vision> (accessed 2.13.21)
- [20] Shelton, T., Zook, M., Wiig, A., 2015. The 'actually existing smart city.' *CAMRES* 8, 13–25.
- [21] Walsh, W. Francis , Brodeur, . Jean-Paul , Whetstone, . Thomas , Banton, . Michael Parker and Kelling, . George L.. "police." *Encyclopedia Britannica*, 17 Dec 2021. <https://www.britannica.com/topic/police>.
- [22] Zumthor, p., 2003. *Thinking the Architecture*. AGM.

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What SMART Can Learn About Art

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Abstract— It is evident that the inherent need for discovery and interaction drives people to explore new places and think of works of art due to an innate drive to gather the information that partly determines what we enjoy doing when we do it. On the other hand, exploring the ways of thinking and types of art in Milton Keynes by illustrating a general pattern of misunderstanding that emphasizes the separation between smartness, art, and architecture. This paper explores the associated understanding of the role and meaning of art and whether it is perceived to be separate from smart city construction. The study promotes a better and deeper understanding of the interconnections between neuroscience, art, and architecture. The study uses a reflective approach that clarifies the potential and impact of using art-based research, methodology, and ways of knowing when approaching global phenomena and knowledge production while examining the process of making and developing smart cities in particular; asserting that it can be severely impacted by factors in the process of conducting the study itself. The study followed a case study as a research strategy. The qualitative methods included data collection and analysis that involved interviews and observations that depended on visuals.

Keywords—Art and city planning, art and smart, residents wellbeing, human needs and urban planning, sustainability, smart cities, Smart

BIBLIOGRAPHY

- [1] Runciman, B., 2020. The Gem of all Mechanisms Computing in society: Kitemarks Apps and Asbestos. ITNOW, 62(2), pp.10-11.
- [2] Runciman, B., 2020. The Gem of all Mechanisms Computing in society: Kitemarks Apps and Asbestos. ITNOW, 62(2), pp.10-11.
- [3] Ellard, C., 2015. Places of the heart: The psychogeography of everyday life. Bellevue literary press.
- [4] Kellert, S.R., Heerwagen, J. and Mador, M., 2011. Biophilic design: the theory, science and practise of bringing buildings to life. John Wiley & Sons.
- [5] Oppong, T., 2020. Psychologists Explain How Emotions, Not logic, Drive Human Behaviour Medium. URL <https://medium.com/personal-growth/psychologists-explain-how-emotions-not-logic-drive-human-behaviour-6ed0daf76e1a> (accessed 2.4.21).
- [6] Niedenthal, P.M., 2007. Embodying emotion. *science*, 316(5827), pp.1002-1005.
- [7] Internal migration: matrices of moves by local authority and region (countries of the UK) - Office for National Statistics (ons.gov.uk), Accessed 19 Feb 2022.
- [8] O'CALLAGHAN, I., 2016, <https://express.co.uk/trem.media/life-style/life/715046/happiest-place-britain-ons-interactive-map-outer-hebrides-orkney-islands>, Accessed 21 Feb 2022.
- [9] Whelan, J., 2020. How to Communicate Change. ITNOW, 62(3), pp.50-51.
- [10] Pallasmaa, J., 1995. The Eyes of the Skin: Architecture and the Senses. John Wiley & Sons.
- [11] Pallasmaa, J., 2009. The Thinking Hand. AD Primer, London.
- [12] Pallasmaa, J., 2011. The Embodied Image. Imagination and Imagery in Architecture. Italia: Editorial Wiley.
- [13] Pallasmaa, J., Pallasmaa, Holl & Pérez-Gómez, S. and Pérez-Gómez, A., 1994. Questions of Perception: Phenomenology of Architecture.
- [14] Zumthor, p., 2003. Thinking the Architecture. AGM.
- [15] Jeffries, S., 2017. 50 reasons to love Milton Keynes (what, only 50?), <https://www.theguardian.com/cities/2017/jan/20/50-reasons-love-milton-keynes-concrete-cows-wd-40>, Accessed 25 Feb 2022.
- [16] Cawley, L., 2017. Milton Keynes: The middle-aged new town.
- [17] <https://www.bbc.co.uk/news/uk-england-beds-bucks-herts-38594140>, Accessed 25 Feb 2022.
- [18] Leach, N., 2016. The UK's friendliest cities revealed: York ranks No1 for community spirit with Wolverhampton the least neighbourly area to live in.
- [19] https://www.dailymail.co.uk/travel/travel_news/article-3949566/the-uk-s-friendliest-hostile-cities-revealed-york-ranks-no1-community-spirit-wolverhampton-neighbourly-area-live-in.html
- [20] Aldridge, J., 2019, Thames Valley Police rated 'inadequate' as inspectors say they're failing victims. <https://www.getreading.co.uk/news/reading-berkshire-news/thames-valley-police-rated-inadequate-16648739>
- [21] Walsh, W. Francis, Brodeur, Jean-Paul, Whetstone, Thomas, Banton, Michael Parker and Kelling, George L., "police." Encyclopedia Britannica, 17 Dec 2021. <https://www.britannica.com/topic/police>.
- [22] Grozdanic, L., 2015. MARC FORNES/THEVERYMANY's ultralight informal amphitheater in France looks like an opening chrysalis. <https://inhabitat.com/marc-fornes-ultralight-informal-amphitheater-in-france-looks-like-an-opening-chrysalis/>, Accessed 09 Mar 2022.
- [23] Salingaros, N.A., 2011. Why monotonous repetition is unsatisfying. arXiv preprint arXiv:1109.1461.
- [24] Wilding, M., 2018. Reclaim the night. Design in the making, The RIBA Journal. <https://www.ribaj.com/culture/architecture-and-the-24-hour-city-london-night-mayor>, Accessed 13 Mar 2022.
- [25] Pacheco, P., 2015. How "eyes on the street" contribute to public safety. The City Fix.
- [26] <https://thecityfix.com/blog/how-eyes-on-the-street-contribute-public-safety-nossa-cidade-priscila-pacheco-kichler/>, Accessed 14 Mar 2022.
- [27] Richardson, M. and Butler, C.W., 2022. Nature connectedness and biophilic design. Building Research & Information, 50(1-2), pp.36-42.
- [28] McLean, K.J., 2019. Nose-first: practices of smellwalking and smellscape mapping. Royal College of Art (United Kingdom).
- [29] Outhwaite, J., 2021. Claims new Hotel La Tour in Milton Keynes is 'blinding' drivers in the morning. Buckingham News.
- [30] <https://www.buckinghamshirelive.com/news/buckinghamshire-news/claims-new-hotel-la-tour-6254234>, Accessed 18 Mar 2022.
- [31] <https://www.uswitch.com/place-to-live/milton-keynes/>, Accessed 21 Feb 2022.
- [32] ons.gov.uk/peoplepopulationandcommunity/wellbeing/bulletins/measuringnationalwellbeing/april2020tomarch2021, Accessed 21 Feb 2022.
- [33] <https://www.bbc.co.uk/news/uk-england-beds-bucks-herts-22038868>, Accessed 21 Feb 2022.

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- [34] <https://cognitiveresearchjournal.springeropen.com/articles/10.1186/s41235-020-00243-4>, 21 Feb 2022.
- [35] <http://cityform.mit.edu/projects/urban-network-analysis>, Accessed 21 Feb 2022.
- [36] <https://twitter.com/kensingtonroyal/status/912626651057487873>, Accessed 21 Feb 2022.
- [37] <https://www.geopunk.co.uk/council/south-northamptonshire-district>, Accessed 22 Feb 2022.
- [38] <https://www.cutemaps.co.uk/product/south-northamptonshire-cute-map-mounted-print/>, Accessed 22 Feb 2022.
- [39] The 9 best things to do in Milton Keynes For Best Tour - (flybirdtaxi.co.uk), Accessed 22 Feb 2022.
- [40] <https://www.woodford-halse-villagesignpost.co.uk/category/county-council/>, Accessed 23 Feb 2022.
- [41] <https://you.38degrees.org.uk/petitions/there-is-a-point-to-saving-the-point-central-milton-keynes-1>, Accessed 23 Feb 2022.
- [42] <https://www.broughtonandmkv-pc.gov.uk/the-parish-council/parish-map/>, Accessed 25.02.2022.
- [43] https://www.facebook.com/MiddletonAndMiltonKeynesVillageCommunityGroup/?ref=page_internal, Accessed 25 Feb 2022.
- [44] <https://www.destinationmiltonkeynes.co.uk/our-story/101-facts-about-mk/#:~:text=Milton%20Keynes%20has%20130%20roundabouts,is%20growing%20all%20the%20time.>, Accessed 25 Feb 2022.
- [45] https://www.cmkn.net/mkcows/history_of_the_real_concrete_cows.shtml, Accessed 25 Feb 2022.
- [46] https://www.dailymail.co.uk/travel/travel_news/article-3949566/The-UK-s-friendliest-hostile-cities-revealed-York-ranks-No1-community-spirit-Wolverhampton-neighbourly-area-live-in.html, Accessed 01 Mar 2022.
- [47] <https://www.ehventures.net/offices/station-house-milton-keynes>, Accessed 01 Mar 2022.
- [48] <https://www.statista.com/statistics/624038/racist-incidents-in-england-and-wales-by-region/>, Accessed 01 Mar 2022.
- [49] https://www.dailymail.co.uk/travel/travel_news/article-3949566/The-UK-s-friendliest-hostile-cities-revealed-York-ranks-No1-community-spirit-Wolverhampton-neighbourly-area-live-in.html, Accessed 01 Mar 2022.
- [50] <https://www.express.co.uk/travel/articles/734987/UK-cities-least-friendly-friendliest-neighbourhoods-york-wolverhampton>, Accessed 01 Mar 2022.
- [51] <https://www.statista.com/statistics/624038/racist-incidents-in-england-and-wales-by-region/>, Accessed 01 Mar 2022.
- [52] <https://www.stophateuk.org/about-hate-crime/racism-in-the-uk/>, Accessed 01 Mar 2022.
- [53] <https://www.victimsupport.org.uk/more-us/about-us/>, Accessed 01 Mar 2022.
- [54] <https://optiware.com/blog/the-importance-of-maintenance-management/#:~:text=Maintenance%20is%20an%20important%20factor,costly%20process%20for%20most%20companies.>, Accessed 02 Mar 2022.
- [55] <https://www.open.edu/openlearn/society-politics-law/sociology/culture-can-be-brutal-just-ask-milton-keynes>, Accessed 02 Mar 2022.
- [56] <https://www.loopnet.com/Listing/321-Avebury-Blvd-Milton-Keynes/19253264/>, Accessed 02 Mar 2022.
- [57] <http://cityform.mit.edu/projects/urban-network-analysis>, Accessed 09 Mar 2022.
- [58] <https://www.pinterest.com/pin/330733166367167732/>, Accessed 09 Mar 2022.
- [59] <https://www.externalworkindex.co.uk/entry/129150/Trueform/M-K-bus-shelter/>, Accessed 09 Mar 2022.
- [60] [https://commons.wikimedia.org/wiki/File:Bath_High_Street_-_First_65726_\(LK55ACJ\)_rear.JPG](https://commons.wikimedia.org/wiki/File:Bath_High_Street_-_First_65726_(LK55ACJ)_rear.JPG), Accessed 10 Mar 2022.
- [61] <https://www.destinationmiltonkeynes.co.uk/things-to-do/arts-and-heritage/mk-gallery/>, Accessed 11 Mar 2022.
- [62] <https://www.architectsjournal.co.uk/buildings/pimp-my-sarsen-mk-menhir-by-sam-jacob-studio>, Accessed 17 Mar 2022.
- [63] <https://cathyreadart.com/contemporary-urban-paintings/milton-keynes-project/>, Accessed 17 Mar 2022.
- [64] Background of Living Archive MK - Creative Placemaking Since The 1970s | About us | Living Archive, Accessed 18 Mar 2022.
- [65] <http://cmktowncouncil.gov.uk/about-the-parish/>, Accessed 21 Feb 2022.
- [66] <https://www.permaculturenews.org/2012/01/04/why-monotonous-repetition-is-unsatisfying/>, Accessed 21 Feb 2022.
- [67] <https://www.permaculturenews.org/2012/01/04/why-monotonous-repetition-is-unsatisfying/>, Accessed 21 Feb 2022.
- [68] <https://slate.com/technology/2015/11/psychology-of-boring-architecture-the-damaging-impact-of-big-ugly-buildings-on-mental-health.html>, Accessed 21 Feb 2022.
- [69] <https://www.theguardian.com/cities/2016/may/03/struggle-for-the-soul-of-milton-keynes>, Accessed 21 Feb 2022.
- [70] Downton, P., Jones, D., Zeunert, J. and Roos, P., 2017, January. Biophilic design applications: theory and patterns into built environment education. In DesTech 2016: Proceedings of the International Conference on Design and Technology (pp. 59-65). Knowledge E.
- [71] <http://cmktowncouncil.gov.uk/about-the-parish/>, Accessed 24.02.2022.
- [72] <https://heritagemk.co.uk/>, Accessed 21 Feb 2022.
- [73] <https://www.loc.gov/item/2014588813/>, Accessed 23 Feb 2022.

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Optimum Tuning Capacitors for Wireless Charging of Electric Vehicles Considering Variation in Coil Distances

Muhammad Abdullah Arafat, and Nahrin Nowrose

Abstract—Wireless charging of electric vehicles is becoming more and more attractive as large amount of power can now be transferred to a reasonable distance using magnetic resonance coupling method. However, proper tuning of the compensation network is required to achieve maximum power transmission. Due to the variation of coil distance from the nominal value as a result of change in tire condition, change in weight or uneven road condition, the tuning of the compensation network has become challenging. In this paper, a tuning method has been described to determine the optimum values of the compensation network in order to maximize the average output power. The simulation results show that 5.2 percent increase in average output power is obtained for 10 percent variation in coupling coefficient using the optimum values without the need of additional space and electro-mechanical components. The proposed method is applicable to both static and dynamic charging of electric vehicles.

Keywords—Coupling coefficient, electric vehicles, magnetic resonance coupling, tuning capacitor, wireless power transfer.

I. INTRODUCTION

ELECTRIC vehicles (EVs) are a clean alternative to conventional internal combustion engine vehicles as it mitigates greenhouse effects and environment pollution. Consequently, EVs are receiving more and more attention and many countries and authorities are putting into electric vehicle (EV) research and development [1], [2]. The main challenges behind the adoption of EVs are the long charging time, the limited driving range constrained by the battery size and the unavailability of adequate charging stations [3]. To overcome these challenges, dynamic WPT technology has emerged [4]. In EV applications, WPT technologies offer several advantages over the conventional plug-in systems by removing charging cables and sockets, eliminating the danger of sparks and electric shock, adapting to harsh weather and environment such as rain and snow, and providing a more safe and reliable charging system to electric vehicles [5]–[7]. In addition, they can be used for both static and dynamic charging of EVs [8], [9]. The magnetic resonance coupling (MRC), a non-radiative WPT technology proposed by MIT researchers in 2007, has shown promising prospect in EV charging due to its efficiency, high power transmission capability to a larger distance and safety compared to other WPT techniques [10]–[12].

The MRC method uses the same principles as inductive coupling, however, it uses resonance to increase the range at which the energy transfer can efficiently take place [13],

[14]. When both the primary (transmitter) and the secondary (receiver) circuits are in the resonant condition, maximum power transfer takes place. For a given transmitter and receiver coils and coil distance, resonance takes place at certain source frequency for certain compensating (tuning) capacitors. For a number of reasons, the distance between the transmitter and receiver coils (d in Fig. 1) can vary from its nominal value. For example, reduction in air pressure and corrosion of tires may reduce the coil distance. Similarly, addition of weight in the EV will also reduce the distance. Moreover, the uneven surface of the road will change the coil distance.

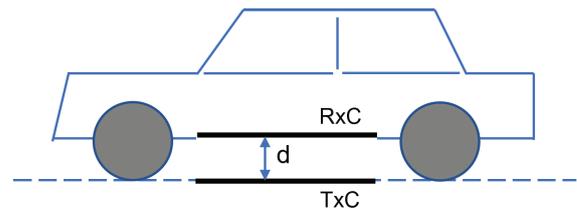


Fig. 1. Schematic of the positions of the transmitter coil (TxC) and receiver coil (RxC) for EV charging system. d is the coil distance.

For smaller coil distance, the mutual inductance between the coils increases and vice versa [15]. The change in mutual inductance results in another set of tuning capacitors to achieve maximum power. Therefore, for systems where the coil distance changes, a tuning mechanism is needed. In automated continuous tuning mechanism, either a servo motor is attached to the variable tuning capacitor and a feedback control circuit is utilized to control the motor to change the capacitance continuously with coil distance, or an array of various capacitors is used and appropriate capacitors are selected by an electronic control circuit [16]. In continuous tuning mechanism, maximum power is obtained at every coil distance within a specified range. However, additional space, control circuits and equipment are required in this mechanism which may not be feasible in all EVs. Considering the variation in coil distances, an alternative tuning method for determining the optimum value of the compensation capacitors has been described in this paper which does not need any additional space and electro-mechanical components. In the proposed method, the optimum value of the compensation network is determined by maximizing the average output power for a given range of coil distance instead of maximizing the output power at specific distances. The method of determining the optimum capacitors is described in the following section.

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The results of using the optimum capacitors are given in Section III. Finally, a conclusion is drawn in Section IV.

II. METHOD

The equivalent circuit diagram of an MRC system is shown in Fig. 2. Since the distance between the transmitter and receiver coils is generally around 20 cm, resonance condition is achieved at 20 cm (nominal value) of coil distance to increase the power transmission for a given source voltage (V_s). Tuning capacitors are added in series or parallel to both the transmitter and receiver coils to achieve the resonance condition. Based on the connection of the tuning capacitors, four types of basic compensation network topology, namely series-series (SS), series-parallel (SP), parallel-series (PS) and parallel-parallel (PP) are used [10], [17]. In this study, analyses are done considering SS topology since it is the most widely used topology among them. In Fig. 2, C_1 and C_2 are the tuning capacitors connected in series with the transmitter and receiver coils, respectively. The source current, I_s and the load current, I_L can be derived as

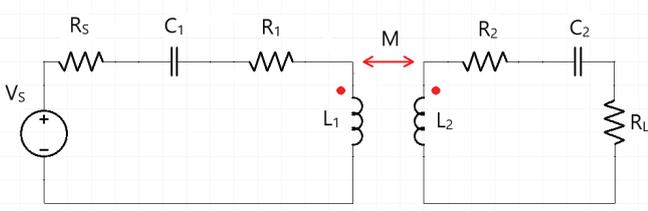


Fig. 2. Equivalent circuit diagram of an MRC system.

$$I_s = \frac{\{R_2 + R_L + j(\omega L_2 - \frac{1}{\omega C_2})\}V_s}{\{R_s + R_1 + j(\omega L_1 - \frac{1}{\omega C_1})\}\{R_2 + R_L + j(\omega L_2 - \frac{1}{\omega C_2})\} + (\omega M)^2} \quad (1)$$

$$I_L = \frac{j\omega M V_s}{\{R_s + R_1 + j(\omega L_1 - \frac{1}{\omega C_1})\}\{R_2 + R_L + j(\omega L_2 - \frac{1}{\omega C_2})\} + (\omega M)^2} \quad (2)$$

where, R_s is the source resistance, R_1 and L_1 are the transmitter coil resistance and self inductance, R_2 and L_2 are the receiver coil resistance and self inductance, M is the mutual inductance, R_L is the load resistance and ω is the source frequency. The output power (P_L) delivered to load is given by

$$P_L = |I_L^2| R_L \quad (3)$$

Conventionally, the values of the tuning capacitors are chosen as such maximum power is delivered to a given load at a given source frequency. The values of the capacitors can be obtained either by using analytical and iterative methods as described in [13] and [18] or by sweeping both the capacitor values to find the peak power. In this study, the later

method has been used to obtain the initial value of the tuning capacitors. Fig. 3 shows the variation of the output power with respect to the tuning capacitors for a system whose equivalent circuit parameters are given in Table I. The maximum output power (908.2 W) occurs at $C_1 = 68.7$ nF and $C_2 = 24.5$ nF for this system at a source frequency of 85 kHz and a coil distance of 20 cm. The mutual inductance between the two coils at this coil distance is $10 \mu\text{H}$ which corresponds to a coupling coefficient of $k = 0.2$.

Let us now assume that the maximum distance between the transmitter coil and the receiver coil of an unloaded EV with new tire and adjusted tire pressure is 20 cm and the maximum change in coil distance is Δd cm due to uneven road surface and variation in weight and tire conditions. The range of operating coil distance is therefore $(20 - \Delta d)$ cm and the corresponding range of coupling coefficient is $(0.2 + \Delta k)$ where Δk is related to the change of mutual inductance, ΔM as follows:

$$\Delta k = \frac{\Delta M}{\sqrt{L_1 L_2}} \quad (4)$$

Simulation results suggest that small change in coil distance has very little effect on the value of the tuning capacitor (C_1) of the transmitter circuit. The value of C_1 therefore remains unchanged. On the other hand, 10% change in coupling coefficient results in 10% change in the tuning capacitor (C_2) of the receiver circuit. Hence, an optimum value of C_2 exists which provides maximum average output power for operating coil distances uniformly distributed in the specified range. In the following part of this section, this optimum value of C_2 is obtained.

TABLE I
EQUIVALENT CIRCUIT PARAMETERS OF AN MRC SYSTEM

Parameter	Value
Transmitter Coil Resistance, R_1	0.01 Ω
Transmitter Coil Self Inductance, L_1	50 μH
Receiver Coil Resistance, R_2	0.01 Ω
Receiver Coil Self Inductance, L_2	50 μH
Mutual Inductance, M	10 μH
Source Resistance, R_s	0.1 Ω
Source Voltage, V_s	20 V
Source Frequency, f_s	85 kHz
Load Resistance, R_L	10 Ω

First, the output power is calculated for the range of coupling coefficient (from k to $k + \Delta k$) using (2) and (3) for various values of C_2 (Fig. 4). The average output power ($P_{L,avg}$) is then calculated by integrating the area under each curve as follows:

$$P_{L,avg} = \int_k^{k+\Delta k} P_L f(x) dx \quad (5)$$

where, $f(x)$ is the probability distribution of k in the specified range. For uniform distribution,

$$f(x) = 1, \quad k \leq x \leq k + \Delta k \quad (6)$$

Therefore, an average output power is obtained for each value of C_2 assuming uniform distribution of k . Fig. 5 shows

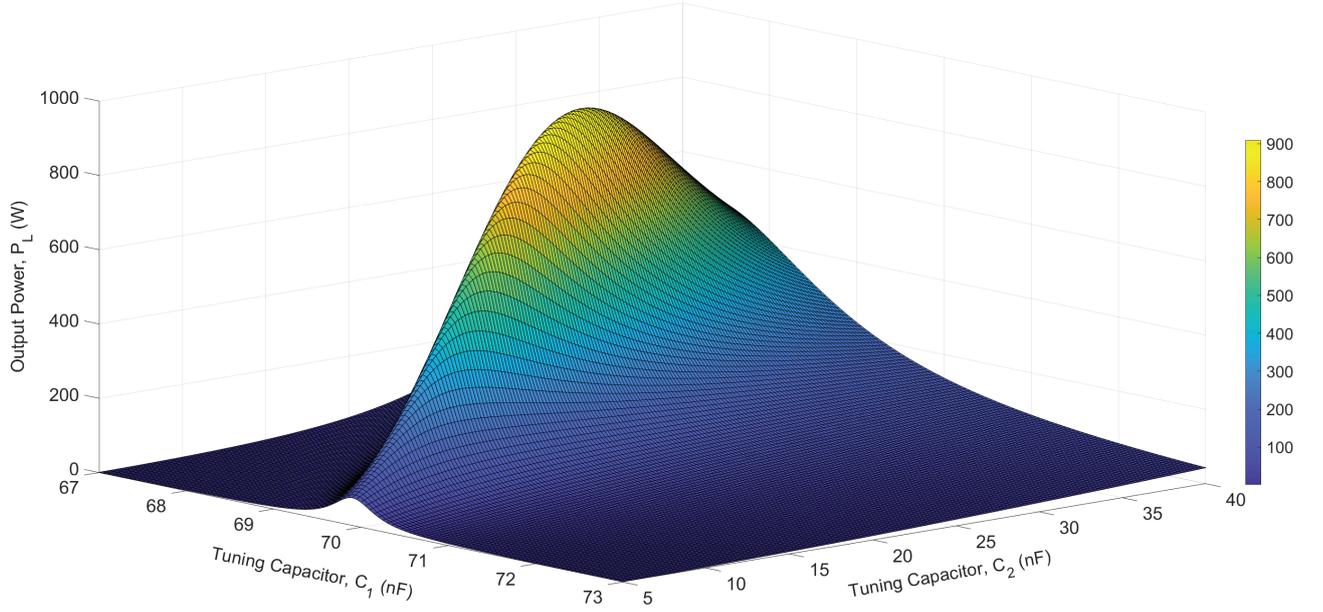


Fig. 3. Variation of output power with tuning capacitors. The peak power (908.2 W) occurs at $C_1 = 68.7$ nF and $C_2 = 24.5$ nF for the system under consideration.

the variation of $P_{L,avg}$ with C_2 and it is seen from the figure that the maximum average output power (887 W) occurs at $C_2 = 23$ nF. In this way, the optimum value of C_2 is obtained for the given range of coil distance.

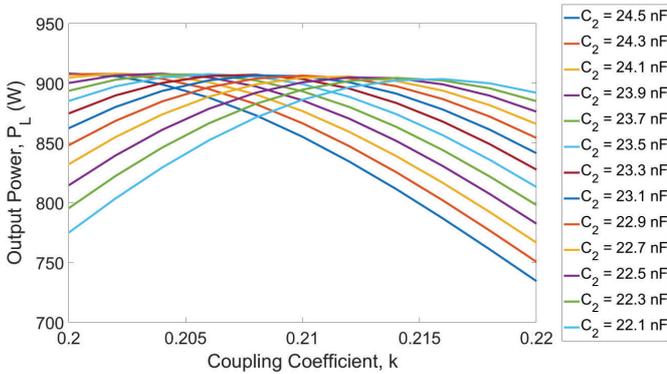


Fig. 4. Profile of output power in the specified range of coupling coefficient for various values of C_2 .

III. RESULTS

Using the method described in the previous section, the optimum values of C_2 are obtained for various ranges of coil distances and depicted in Fig. 6. The figure shows that the optimum value of C_2 varies with the range of coil distance. The more the range of coil distance is, the more the deviation of C_2 is from the initial tuning value corresponding to the nominal coil distance (20 cm). The amount of power that has been increased by using the optimum tuning capacitors for

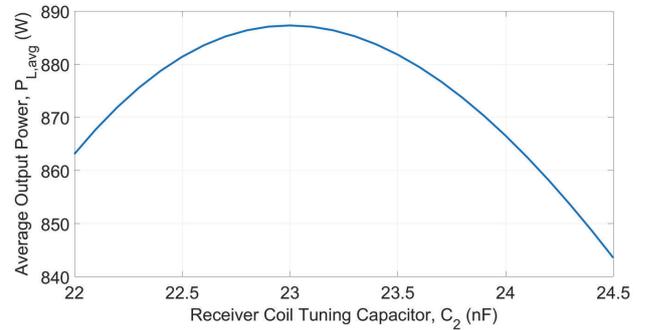


Fig. 5. Plot of average output power versus transmitter coil tuning capacitor C_2 . Maximum average power (887 W) occurs at 23 nF.

various ranges of coil distance is shown in Fig. 7 along with the maximum power that could be obtained using continuous tuning method. It is obvious from the figure that although the average output power obtained by using capacitors optimized for a given range of coil distance is less than the average output power obtained by continuous tuning system, it is higher than the average output power that would have been obtained by using initial tuning capacitors (fixed tuning system). About 5.2% increase in average output power is obtained for 10% variation in coupling coefficient using the optimum values without using any additional circuitry. Although the proposed method has been demonstrated using a specific system given in Table I, similar results can be obtained for other systems.

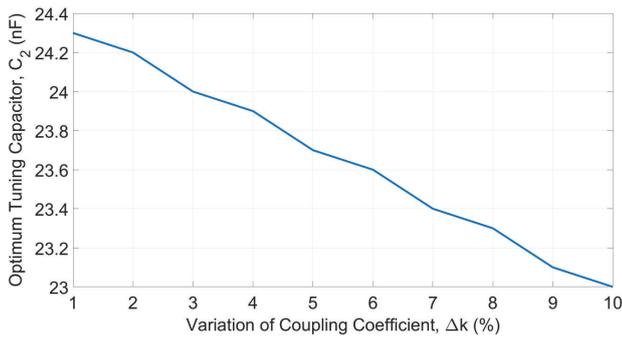


Fig. 6. Optimum values of tuning capacitor C_2 for various ranges of coil distance.

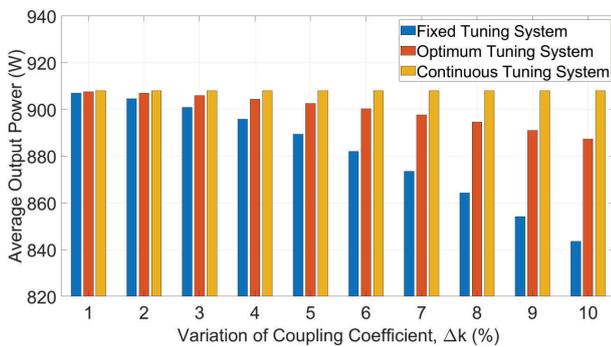


Fig. 7. Comparison of average output power for the three types of tuning systems.

IV. CONCLUSION

In this study, the value of tuning capacitors optimized for a range of operating coil distance is determined. When automatic continuous tuning system is not feasible, the proposed method provides better output power than the fixed tuning system. All the three tuning methods provide the same output power for zero variation of coil distance. In the analysis, a uniform probability distribution of coil distance within the specified range has been assumed. A more practical distribution of coil distance would provide better tuning to increase output power. Similar analysis could also be carried out for other types of compensation topology. The proposed method could be used to tune the compensation capacitors for both static and dynamic charging of EVs where the coil distance varies within a range due to tire pressure change, weight change and roughness of the road.

REFERENCES

- [1] A. Mahdavian, A. Shojaei, S. McCormick, T. Papandreou, N. Eluru, and A. A. Oloufa, "Drivers and barriers to implementation of connected, automated, shared, and electric vehicles: An agenda for future research," *IEEE Access*, vol. 9, pp. 22 195–22 213, 2021.
- [2] R. Bosshard and J. W. Kolar, "Inductive power transfer for electric vehicle charging: Technical challenges and tradeoffs," *IEEE Power Electronics Magazine*, vol. 3, no. 3, pp. 22–30, 2016.
- [3] B. Al-Hanahi, I. Ahmad, D. Habibi, and M. A. S. Masoum, "Charging infrastructure for commercial electric vehicles: Challenges and future works," *IEEE Access*, vol. 9, pp. 121 476–121 492, 2021.
- [4] C. C. Mi, G. Buja, S. Y. Choi, and C. T. Rim, "Modern advances in wireless power transfer systems for roadway powered electric vehicles," *IEEE Transactions on Industrial Electronics*, vol. 63, no. 10, pp. 6533–6545, 2016.
- [5] Y. Jiang, L. Wang, Y. Wang, J. Liu, M. Wu, and G. Ning, "Analysis, design, and implementation of wpt system for ev's battery charging based on optimal operation frequency range," *IEEE Transactions on Power Electronics*, vol. 34, no. 7, pp. 6890–6905, 2019.
- [6] M. Kabalo, F. Berthold, B. Blunier, D. Bouquain, S. Williamson, and A. Miraoui, "Efficiency comparison of wire and wireless battery charging: Based on connection probability analysis," in *2014 IEEE Transportation Electrification Conference and Expo (ITEC)*, 2014, pp. 1–6.
- [7] A. Mahesh, B. Chokkalingam, and L. Mihet-Popa, "Inductive wireless power transfer charging for electric vehicles—a review," *IEEE Access*, vol. 9, pp. 137 667–137 713, 2021.
- [8] V. Cirimele, J. Colussi, J. L. Villa, A. L. Ganga, and P. Guglielmi, "Modelling of a 100 kw-85 khz three-phase system for static wireless charging and comparison with a classical single-phase system," in *2020 IEEE International Symposium on Circuits and Systems (ISCAS)*, 2020, pp. 1–5.
- [9] Z. Wang, S. Cui, S. Han, K. Song, C. Zhu, M. I. Matveevich, and O. S. Yurievich, "A novel magnetic coupling mechanism for dynamic wireless charging system for electric vehicles," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 1, pp. 124–133, 2018.
- [10] X. Mou, D. T. Gladwin, R. Zhao, and H. Sun, "Survey on magnetic resonant coupling wireless power transfer technology for electric vehicle charging," *IET Power Electronics*, vol. 12, pp. 3005–3020(15), October 2019. [Online]. Available: <https://digital-library.theiet.org/content/journals/10.1049/iet-pel.2019.0529>
- [11] L. Shuang and J. Jia, "Review of ev's wireless charging technology," in *2019 IEEE 2nd International Conference on Electronics and Communication Engineering (ICECE)*, 2019, pp. 128–132.
- [12] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljacic, "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, no. 5834, pp. 83–86, 2007.
- [13] D.-W. Seo, J.-H. Lee, and H.-S. Lee, "Optimal coupling to achieve maximum output power in a wpt system," *IEEE Transactions on Power Electronics*, vol. 31, no. 6, pp. 3994–3998, 2016.
- [14] R. Yan, X. Guo, S. Cao, and C. Zhang, "Optimization of output power and transmission efficiency of magnetically coupled resonance wireless power transfer system," *AIP Advances*, vol. 8, no. 5, p. 056625, 2018. [Online]. Available: <https://doi.org/10.1063/1.5007276>
- [15] H. Tavakkoli, E. Abbaspour-Sani, A. Khalilzadegan, A.-M. Abazari, and G. Rezazadeh, "Mutual inductance calculation between two coaxial planar spiral coils with an arbitrary number of sides," *Microelectronics Journal*, vol. 85, pp. 98–108, 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S002626921830483X>
- [16] S. Hou, B. Yu, W. Yan, C. Zhu, K. Wang, and Z. Wu, "Analysis of assistant reactive shielding coil for electric vehicle wireless charging system," in *2020 IEEE International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA)*, vol. 1, 2020, pp. 798–802.
- [17] C. Panchal, S. Stegen, and J. Lu, "Review of static and dynamic wireless electric vehicle charging system," *Engineering Science and Technology, an International Journal*, vol. 21, no. 5, pp. 922–937, 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S221509861830154X>
- [18] D.-W. Seo and J.-H. Lee, "Method for estimating optimum free resonant frequencies in overcoupled wpt system," *International Journal of Antennas and Propagation*, vol. 2017, pp. 1–6, 2017.

A Multi-population DE with Adaptive Mutation and Local Search for Global Optimization

Zhoucheng Bao, Haiyan Zhu, Tingting Pang, Zuling Wang

Abstract—This paper proposes a multi population DE with adaptive mutation and local search for global optimization, named AMMADE. The AMMADE aim to coordinate the cooperation between the populations and make use of resource reasonably. In AMMADE, at each generation, the population is divided by using the Euclidean distance sorting method, which could appropriately coordinate the cooperation between subpopulations and the usage of resources. Such that the best-performed subpopulation will get more computing resources in the next generation. Further, an adaptive local search strategy is employed to achieve a balanced search according to best-performed subpopulation. The proposed algorithm has been tested by solving optimization problems taken from CEC2014 benchmark problems. Experimental results show that our algorithm can achieve a competitive or better than related methods. The results also confirm the significance of devised strategies in the proposed algorithm.

Keywords—Differential evolution, multi-mutation strategies, memetic algorithm, adaptive local search.

I. INTRODUCTION

DIFFERENTIAL evolution (DE) is a population-based stochastic search technique. It uses mutation, crossover, and selection operators at each generation to move its population toward the global optimum [1]. Due to its simplicity and efficiency, DE has been successfully applied to many fields. Generally, the performance of DE relies on recombination strategies, parameters as well as the population structure [2]. Typically, different problems requires different mutation strategies and parameter settings [3]. To appropriately use mutation strategies, a commonly approach is to adaptively control the mutation strategies and parameters [4].

Many DE variants with adaptive mutation strategy and/or parameter control have been proposed in literature. For example, JADE [5] employed a parameter adaptation strategy along with DE/current-to-pbest mutation strategy to generate new solutions. In EPSDE [4], using mutation operator pool and crossover operator pool to generate competitive offspring. CoDE [6] is designed to control parameters based on a composite trial vector generation strategies, in which three trial vector generation strategies namely DE/rand/1, DE/rand/2 and DE/current-to-rand/1 are employed. SaDE [7] used trial vector generation strategy and parameter adaptation strategy to match different phases of search process. These mutation strategies in the above algorithms are employed on one single

population and each mutation strategy is assigned with the same computational resources, which may lead to a waste of resources. Individual mutation strategies at each stage may have a different performance and a good strategy should be assigned with more computing resources [8].

In recent years, the integration of multiple mutation strategies into multiple subpopulations has also attracted attention. For example, MPEDE [9], a multi-population based DE, realized a dynamic ensemble of multiple mutation strategies. In MPEDE, the author tried to divide the population into a larger reward sub-population and three smaller equal indicator subpopulations. Firstly, three indicator subpopulations are assigned to three mutation strategies, respectively. Then, the reward subpopulation is randomly assigned to one of the three mutation strategies. After a certain number of generations, the reward subpopulation is assigned to the best mutation strategy [8]. The three mutation strategies contain DE/current-to-pbest/1 with an archive, DE/current-to-rand/1, and DE/rand/1. Among them, the DE/current-to-pbest/1 with an archive is very competitive in solving complex optimization problems, especially those with unimodal and multimodal landscapes. And, DE/current-to-rand/1 without crossover operation is a rotation-invariant and useful in solving rotated problem. Besides, the DE/rand/1 strategy has a strong exploration capability and can effectively maintain the diversity of populations [5], [8], [9]. The control parameters of MPEDE is based on the scheme proposed in JADE. However, in MPEDE, most computing resources are allocated to the best strategy, while the mutation strategy employed by the individual is random, which may not be effective.

To improve the efficiency of DE, memetic DE [10] has been proposed. For example, Rogalsky and Derksen [11] combined downhill simplex (DS) with DE to accelerate convergence. Daniel Molina et al [12] proposed a memetic DE called SHADE-ILS for large-scale global optimization, which combined SHADE [13] with ILS [14]. In these algorithms, the memetic DE are achieved by a single local search method in single population or multi-population, which may have difficulty to balance exploration and exploitation.

In this paper, AMMADE with two strategies are proposed based on MPEDE to address global optimization problems. Different from the grouping of MPEDE, the reward population is removed in AMMADE and the entire population is divided into three subpopulations with the same size. At each generation, a main subpopulation is obtained on the basis of the performance of the three subpopulations. The main population will be assigned with a more computing resources at each generation. At the same time, a new sorting

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method based on Euclidean distance is adopted to partition the population. At each generation, individuals will adopt a suitable mutation strategy to improve a reasonable utilization of resources. Finally, an adaptive local search is introduced into the main subpopulation in order to balance exploration and exploitation. Taking into account the limitation of computing resources, when the diversity of the population is small, the Cauchy local search is used for these outstanding individuals in the main subpopulation, otherwise the Gaussian local search is used to improve the performance of the best individual of the main subpopulation. Experiments show that the performance of AMMADE is competitive or better than JADE [5], SaDE [7], EPSDE [4], CoDE [6] and MPEDE [9].

The rest of this paper is arranged as follows. In Section II, the related work is briefly reviewed. AMMADE algorithm is described in detail in Section III. Section IV gives the comparison results with other algorithms. Finally, Section V concludes this paper.

II. RELATED WORK

The DE algorithm initializes the population of NP candidate solutions randomly, $X_i = \{x_i^1, \dots, x_i^D\}$ $i = 1, \dots, NP$ and explores the search space by sampling on the D -dimensional space. After population initialization, the DE algorithm will undergo a generational evolution, which consists of three operations: mutation, crossover and selection.

The mutation strategy has a great impact on the performance of the algorithm, and the DE algorithm generates a new solution through the corresponding mutation strategy in each generation to find the best fitness value. The commonly used mutation strategies in the past few years are as follows:

- 1) DE/best/1

$$V_i = X_{best} + F_i \cdot (X_{r2} - X_{r1}) \quad (1)$$

- 2) DE/rand/1

$$V_i = X_{r3} + F_i \cdot (X_{r2} - X_{r1}) \quad (2)$$

- 3) DE/current-to-pbest/1

$$V_i = X_i + F_i \cdot (X_{pbest}^p - X_i) + F_i \cdot (X_{r2} - X_{r1}) \quad (3)$$

- 4) DE/current-to-rand/1

$$V_i = X_i + F_i \cdot (X_{r3} - X_i) + F_i \cdot (X_{r2} - X_{r1}) \quad (4)$$

where X_{best} denotes the best parent vector in the current population, X_{pbest}^p is randomly chosen from the top $100 * p\%$ individuals in the current population, F_i commonly known as the scaling factor to control the rate of evolution of the population. The indices r_1, r_2, r_3 are randomly generated a new for each mutant vector and are mutually exclusive ($r_1 \neq r_2 \neq r_3$).

After the mutation, DE then undergoes a crossover operation to generate a trial vector U_i . Commonly used crossover strategies are binomial crossover and exponential crossover. The binomial crossover is defined as follows.

$$U_i^j = \begin{cases} V_i^j, & \text{if } rand[0,1] \leq C_r \text{ or } j = j_{rand}, \\ X_i^j, & \text{otherwise.} \end{cases} \quad (5)$$

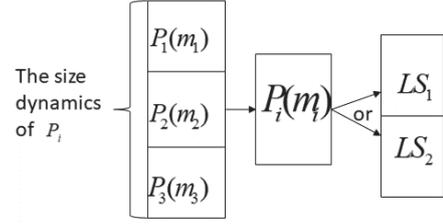


Fig. 1: Algorithm Structure Diagram

where $C_r \in (0, 1]$ is crossover probability, which controls the number of decision variable values. j_{rand} is a random number to ensure that at least one number is always selected from the mutant vector V_i .

After the mutation and crossover operation, election operation will be employed. The selection operation is a process of elimination and screening of old and new individuals (V_i and U_i) based on fitness values. The selection operation is defined as:

$$X_i = \begin{cases} U_i, & \text{if } f(U_i) \leq f(X_i) \\ X_i, & \text{otherwise.} \end{cases} \quad (6)$$

where $f(U_i)$ and $f(X_i)$ are the fitness values of U_i and X_i , respectively.

III. PROPOSED ALGORITHM

In this section, we present the detailed process and strategy of our algorithm. First, population is initialized randomly, calculating the fitness value of each individual and the Euclidean distance to the best individual. Unlike MPEDE [9], we rank individuals according to the Euclidean distance to the best individual, and then divided the population into three subpopulations of the same size. Then, three mutation strategies is employed for the three subpopulations. The top ranking subpopulation use DE/rand/1 as mutation strategy, the medium ranking subpopulation adopt DE/current-to-rand/1 and the worst ranking population apply DE/current-to-pbest/1. The three subpopulations share the best individual information according to the fitness value to accelerate the convergence of subpopulations. The three sub-populations will run in parallel, and the most potential subpopulation P_{main} is obtained according to the indicator. An adaptive local search operation is performed on P_{main} , and the P_{main} will get more computing resources through the population migration strategy in the next generation. Finally, when the computing resources are used up, the best individual of the population and its fitness value are output. The diagram of MAs and the overview of the proposed algorithm are shown in Figure 1 and Algorithm 1, respectively.

In 1, the left part represents three subpopulations with different mutation/crossover operators. The size of the three sub populations is the same at first, and then will change dynamically according to their respective performance. The middle part represents the main population, and the right part represents two different local search methods.

In the following subsections, we will describe the adaptive mutation operator strategy based on multi-populations in Section III-A, and the adaptive local search strategy in Section III-B.

A. Adaptive Mutation Operator Strategy Based on Multi-populations

In AMMADE, three subpopulations use different mutation strategies at each generation according to the ranking of the Euclidean distance, and use a new resource allocation method, a better mutation strategy will get more computing resources. The specific operation is as follows.

Firstly, the population is divided into three equal-sized subpopulations according to the individual's Euclidean distance ranking in AMMADE. The top subpopulation has less diversity, and use DE/rand/1 mutation strategy to increase its diversity. The worst-ranked subpopulation has enough diversity, but the convergence speed is slow, thereby mutation strategy DE/current-to-pbest/1 will be used to improve the convergence speed. During the run of three sub-populations, the most potential subpopulation is formed according to index SQF_p . Three new subpopulations are generated after population reordering, and migrate the top p_m individuals of the two populations with poor potential to the main subpopulation P_{main} . The index SQF_p is used to judge the potential of each subgroup and is defined as follows.

Considering the diversity of each sub population, the proportion of each sub population to the diversity of all subpopulations $DS_p \in [0, 1]$ is calculated according to Equation 7.

$$DS_p = \frac{\frac{1}{NP_p} \left(\sum_{i=1}^{NP_p} \text{dis}(\vec{P}_{p,i} - \vec{P}_{p,best}) \right)}{\sum_p \frac{1}{NP_p} \left(\sum_{i=1}^{NP_p} \text{dis}(\vec{P}_{p,i} - \vec{P}_{p,best}) \right)}, \forall p = 1, 2, 3 \quad (7)$$

where $\text{dis}(\vec{P}_{p,i} - \vec{P}_{p,best})$ is the Euclidean distance from each individual to the best individual of P_{main} . Considering the potential of each subpopulation from the best fitness value, which in equation 8.

$$QF_p = \frac{\text{fitness}P_{p,best}}{\sum_{p=1}^3 \text{fitness}P_{p,best}}, \forall p = 1, 2, 3 \quad (8)$$

Considering the quality and diversity of solutions, the larger the value of IFB_p , the better the potential to find the optimal value representing the sub population.

$$IFB_p = (1 - QF_p) + DS_p * (n_{fes} / \max_n_{fes}), \forall p = 1, 2, 3 \quad (9)$$

Finally, considering the dynamic situation of optimization, the index SQF_p is finally based on the performance of the last three generations, which is shown in Equation 10.

$$SQF_p = \begin{cases} IFB_{p,g}, g = 1 \\ \frac{1}{2} * \sum_{g=gen-1}^{gen} IFB_{p,g}, g \geq 2, \forall p = 1, 2, 3 \end{cases} \quad (10)$$

where gen is the number of current running generation.

B. Adaptive Local Search Strategy

It has been well established that, keeping the balance between exploration and exploitation is very important to improve the performance of DE algorithm. At the later stage of evolution, the algorithm should pay more attention to exploitation, thus accurately identifying the optimum [15]. We perform a local search operation on the top 2% individuals in the most potential subpopulation, when the index of population diversity LST is 1, the Cauchy local search method is used to enhance the population diversity, otherwise, the Gaussian local search is performed to further optimize the solution. The Gaussian local search and Cauchy local search are shown in equation 11 and equation 12, respectively.

$$x_{new} = \text{Normrnd}(x_{old}, e^{-(n_{fes} / \max_n_{fes})^2}) \quad (11)$$

As the iterative process $e^{-(n_{fes} / \max_n_{fes})^2}$ becomes smaller, the variation range of x_{new} changes is reduced, and the exploitation is more focused.

$$X_{i,new} = \text{Cauchy}(X_{i,old}, e^{-1+(n_{fes} / \max_n_{fes})^2}) \quad (12)$$

As the iterative process $e^{-1+(n_{fes} / \max_n_{fes})^2}$ becomes larger, the variation range of $X_{i,new}$ expands, and the diversity of the main population can increase, which is conducive to exploration.

The change rate of the average value of the solution of the most potential subpopulation P_{main} in the last five generations $DivR_{gen}$, which in Equation 13, it will gradually become smaller.

$$DivR_{gen} = \frac{\text{abs}(Div_{gen} - Div_{gen-5})}{Div_{gen-5}} \quad (13)$$

where Div_{gen} is the diversity of the sub population P_{main} , which is shown in equation 14.

$$Div_{gen} = \frac{1}{NP_{gen}} \left(\sum_{i=1}^{NP_{gen}} \text{dis}(\vec{P}_{gen,i} - \vec{P}_{gen,best}) \right) \quad (14)$$

The index LST taking into account the limitation of computing resources and the reduction of population diversity in the later period. When the LST is 1, it means that the diversity of the population is low, and the Cauchy local search needs to be added.

$$LST = \begin{cases} 1, e^{-DivR} > e^{-(n_{fes} / \max_n_{fes})^3} \\ 0, otherwise \end{cases} \quad (15)$$

IV. EXPERIMENTS

TABLE I: SUMMARY OF THE PARAMETER VALUES USED IN THE PROPOSED ALGORITHM

Parameters	$popsize$	mF_i	mCR_i	p	p_m
Value	210	0.5	0.5	0.05	0.05

In this section, extensive experiments have been carried out to evaluate the AMMADE's performance. First, in Section IV-A, the parameter setting of algorithm and function is mentioned. In Section IV-B, we explore the effectiveness of

Algorithm 1 AMMADE algorithm.

- 1) Set the initial global parameters $gen=0$, population size $popsiz$ e and population mobility p_m .
- 2) Calculate the Euclidean distance from each individual to the best individual and sort it order.
- 3) Set the initial parameters of the subpopulation $mF_i, mCR_i, NP_i=popsiz/3, i = 1, 2, 3$
- 4) According to the sorting, divide three sub-populations P_i and use different mutation strategies, P_1 ("DE/rand/1" for the top ranking), P_2 ("DE/current-to-rand/1" for the general ranking) and P_3 ("DE/current-to-pbest/1" for the worst ranking)
- 5) Repeat the following process until a predefined termination condition is met.
 - a) The three subpopulations P_i evolve in parallel with different mutation m_i operators and return to $P_i, fitnessP_i, NP_i$.
 - b) Get the $score_i$ according to index SQF_p , and the population with the highest score is the most potential population P_{main} .
 - c) Adaptive Local search for P_{main} , which is shown in Algorithm 3.
 - d) Implement population migration strategy, which is shown in Algorithm 2.
- 6) Output the solution with the best fitness in the terminal population.

Algorithm 2 Implement population migration strategy.

- 1) Calculate and sort the Euclidean distance from each individual to the best individual.
- 2) Re-divide sub-populations according to sorting
- 3) **if** $P_1 == P_{main}$
 - a) Migrate the top p_m individuals from P_3 to P_1 .
 - b) Migrate the top p_m individuals from P_2 to P_1 .
- 4) **else if** $P_2 == P_{main}$
 - a) Migrate the top p_m individuals from P_3 to P_2 .
 - b) Migrate the top p_m individuals from P_1 to P_2 .
- 5) **else if** $P_3 == P_{main}$
 - a) Migrate the top p_m individuals from P_2 to P_3 .
 - b) Migrate the top p_m individuals from P_1 to P_3 .
- 6) **end if**
- 7) Sort according to fitness value, replace the best individuals of the three subpopulations with the best individuals of the entire population
- 8) update $P_i, fitnessP_i, NP_i$.

TABLE II: COMPARISON OF RESULTS IN TERMS OF MEAN (STD) ON THE CEC2014 TEST FUNCTIONS WITH D=30

Functions	MPEDA	AMMADE_1	AMMADE
	Mean (Std)	Mean (Std)	Mean (Std)
F1	1.08E-03 (7.70E-03)	6.96E-03(4.88E-02)	2.48E-06(1.10E-05)
F2	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F3	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F4	8.30E-04(5.93E-03)	4.29E-07 (3.06E-06)	1.56E-11 (7.04E-11)
F5	2.04E+01(4.22E-02)	2.03E+01 (4.75E-02)	2.03E+01 (6.46E-02)
F6	9.00E-01 (1.09E+00)	2.62E+00(1.64E+00)	1.77E+00(1.53E+00)
F7	3.38E-04 (1.71E-03)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F8	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F9	2.82E+01(7.30E+00)	2.44E+01 (6.20E+00)	2.37E+01 (5.07E+00)
F10	1.30E+00(8.26E-01)	5.28E-02 (5.07E-02)	6.20E-02(3.72E-02)
F11	2.39E+03(4.62E+02)	1.97E+03 (4.07E+02)	1.93E+03 (4.07E+02)
F12	5.22E-01(9.50E-02)	4.05E-01 (8.49E-02)	4.24E-01 (8.00E-02)
F13	2.10E-01 (7.42E-02)	2.19E-01 (3.59E-02)	2.08E-01 (3.22E-02)
F14	2.37E-01(3.20E-02)	2.25E-01 (2.59E-02)	2.22E-01 (2.66E-02)
F15	4.03E+00(8.44E-01)	3.17E+00 (7.13E-01)	3.36E+00 (7.79E-01)
F16	9.97E+00(4.38E-01)	9.76E+00 (4.19E-01)	9.66E+00 (4.54E-01)
F17	2.17E+02 (1.55E+02)	3.10E+02(1.68E+02)	2.80E+02 (1.71E+02)
F18	1.44E+01(5.26E+00)	1.27E+01 (5.13E+00)	1.24E+01 (4.04E+00)
F19	3.81E+00 (5.32E-01)	3.84E+00 (5.82E-01)	3.86E+00 (5.47E-01)
F20	8.66E+00 (2.77E+00)	1.07E+01(4.22E+00)	1.03E+01(3.25E+00)
F21	1.02E+02 (1.06E+02)	1.44E+02(1.43E+02)	1.48E+02(9.46E+01)
F22	8.93E+01 (6.37E+01)	9.93E+01(7.16E+01)	8.12E+01 (6.01E+01)
F23	3.15E+02 (4.59E-13)	3.15E+02 (3.21E-12)	3.15E+02 (3.21E-12)
F24	2.25E+02(3.37E+00)	2.24E+02 (6.65E-01)	2.24E+02 (5.87E-01)
F25	2.00E+02 (2.30E-03)	2.03E+02(2.99E-01)	2.03E+02(4.52E-01)
F26	1.00E+02 (2.77E-02)	1.00E+02 (2.98E-02)	1.00E+02 (3.25E-02)
F27	3.55E+02 (4.89E+01)	3.76E+02 (4.30E+01)	3.66E+02 (4.55E+01)
F28	8.35E+02(3.77E+01)	7.92E+02 (2.84E+01)	7.95E+02 (3.00E+01)
F29	6.84E+02 (1.33E+02)	6.97E+02 (9.94E+01)	6.73E+02 (1.51E+02)
F30	7.62E+02(3.87E+02)	6.92E+02(2.16E+02)	6.75E+02 (3.58E+02)
	13/11/6	4/25/1	+/-/=

the proposed strategy. Finally, we compare the performance of our method with related methods.

All algorithms are run with a computer of Intel Core i78700 3.20 GHz CPU, 16 GB RAM. We run each algorithm 51 times on each test problem and record the means (mean) and standard deviations (std) of function values among these runs. On each problem, the best mean fitness values among the algorithms to be compared are marked with boldface in the results.

A. Experimental Settings

To verify the performance of proposed algorithm, we conduct numerical experiments on the CEC2014 test suites. The data sets of CEC2014 can be categorized into four groups, F1-F3 are uni-modal functions, F4-F16 are the simple multi-modal functions, F17-F22 are the hybrid functions and F23-F30 are composition functions. For all problems, the search

TABLE III: COMPARISON OF RESULTS IN TERMS OF MEAN (STD) ON THE CEC2014 TEST FUNCTIONS WITH D=30

Functions	JADE	CoDE	SaDE	EPSDE	MPEDE	AMMADE
	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)
F1	2.81E+03(3.07E+03)	2.23E+04(1.75E+04)	3.66E+05(2.34E+05)	8.53E+04(5.60E+05)	1.08E-03 (7.70E-03)	2.48E-06(1.10E-05)
F2	0.00E+00 (0.00E+00)	5.76E+00(2.44E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F3	1.13E-06(7.51E-06)	1.49E-04(6.86E-05)	2.70E+01(6.12E+01)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F4	0.00E+00 (0.00E+00)	2.72E+01(2.67E+01)	4.04E+01(3.78E+01)	3.73E+00(2.24E+00)	8.30E-04(5.93E-03)	1.56E-11(7.04E-11)
F5	2.03E+01 (3.53E-02)	2.06E+01(4.33E-02)	2.05E+01(5.08E-02)	2.04E+01(4.04E-02)	2.04E+01(5.41E-02)	2.03E+01 (6.46E-02)
F6	1.00E+01(2.12E+00)	2.17E+01(1.84E+00)	5.11E+00(2.01E+00)	1.88E+01(1.58E+00)	9.00E-01 (1.09E+00)	1.77E+00(1.53E+00)
F7	1.45E-04 (1.04E-03)	5.65E-04(3.08E-03)	7.13E-03(1.18E-02)	1.45E-03(4.88E-03)	3.38E-04 (1.71E-03)	0.00E+00 (0.00E+00)
F8	0.00E+00 (0.00E+00)	1.86E+01(1.38E+00)	1.95E-02(1.39E-01)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F9	2.69E+01(3.59E+00)	1.38E+02(9.84E+00)	4.20E+01(1.03E+01)	4.36E+01(5.80E+00)	2.82E+01(7.30E+00)	2.14E+01 (4.81E+00)
F10	5.72E-03 (1.18E-02)	7.73E+02(8.33E+01)	2.67E-01(4.23E-01)	2.49E-01(2.33E-01)	1.30E+00(8.26E-01)	6.20E-02(3.72E-02)
F11	1.65E+03 (2.49E+02)	4.82E+03(2.57E+02)	3.22E+03(5.85E+02)	3.53E+03(3.62E+02)	2.39E+03(4.62E+02)	1.93E+03(4.07E+02)
F12	2.58E-01 (3.33E-02)	1.01E+00(1.56E-01)	7.68E-01(9.97E-02)	5.01E-01(5.48E-02)	5.22E-01(9.50E-02)	4.24E-01(8.00E-02)
F13	2.06E-01 (2.96E-02)	4.49E-01(5.15E-02)	2.57E-01(4.09E-02)	2.44E-01(3.62E-02)	2.10E-01(7.42E-02)	2.08E-01 (3.22E-02)
F14	2.19E-01 (3.42E-02)	2.87E-01(3.77E-02)	2.29E-01 (3.62E-02)	2.92E-01(7.42E-02)	2.37E-01(3.20E-02)	2.22E-01 (2.66E-02)
F15	3.24E+00 (3.44E-01)	1.36E+01(9.60E-01)	4.83E+00(1.79E+00)	5.39E+00(7.94E-01)	4.03E+00(8.44E-01)	3.36E+00 (7.79E-01)
F16	9.38E+00 (4.33E-01)	1.16E+01(2.47E-01)	1.10E+01(3.11E-01)	1.11E+01(3.45E-01)	9.97E+00(4.38E-01)	9.66E+00(4.54E-01)
F17	1.62E+04(1.08E+05)	1.47E+03(2.25E+02)	1.27E+04(1.10E+04)	4.27E+04(4.08E+04)	2.17E+02 (1.55E+02)	2.80E+02 (1.71E+02)
F18	6.96E+01(3.18E+01)	4.96E+01(5.63E+00)	4.38E+02(6.73E+02)	2.24E+02(4.14E+02)	1.44E+01(5.26E+00)	1.24E+01 (4.04E+00)
F19	4.34E+00(6.88E-01)	7.12E+00(8.33E-01)	5.33E+00(8.29E+00)	1.33E+01(1.16E+00)	3.81E+00 (5.32E-01)	3.86E+00 (5.47E-01)
F20	2.39E+03(2.61E+03)	3.06E+01(3.88E+00)	1.37E+02(1.90E+02)	5.61E+01(7.03E+01)	8.66E+00 (2.77E+00)	1.03E+01(3.25E+00)
F21	2.92E+03(1.89E+04)	7.19E+02(1.28E+02)	3.73E+03(5.32E+03)	8.04E+03(9.02E+03)	1.02E+02 (1.06E+02)	1.48E+02(9.46E+01)
F22	1.59E+02(7.08E+01)	1.20E+02(5.20E+01)	1.37E+02(5.70E+01)	2.25E+02(9.13E+01)	8.93E+01 (6.37E+01)	8.12E+01 (6.01E+01)
F23	3.15E+02(3.21E-12)	3.15E+02(6.02E-07)	3.15E+02(2.76E-12)	3.14E+02 (1.38E-12)	3.15E+02(4.59E-13)	3.15E+02(3.21E-12)
F24	2.25E+02(1.14E+00)	2.26E+02(8.06E-01)	2.26E+02(2.51E+00)	2.29E+02(6.06E+00)	2.25E+02(3.37E+00)	2.24E+02 (5.87E-01)
F25	2.05E+02(1.89E+00)	2.00E+02(7.28E-02)	2.08E+02(3.17E+00)	2.00E+02 (1.73E-01)	2.00E+02(2.30E-03)	2.03E+02(4.52E-01)
F26	1.00E+02 (3.50E-02)	1.00E+02(4.68E-02)	1.02E+02(1.40E+01)	1.00E+02(4.27E-02)	1.00E+02 (2.77E-02)	1.00E+02 (3.25E-02)
F27	3.39E+02 (4.75E+01)	4.01E+02(2.22E-01)	4.04E+02(3.19E+01)	8.44E+02(9.13E+01)	3.55E+02(4.89E+01)	3.66E+02(4.55E+01)
F28	7.94E+02(3.56E+01)	9.39E+02(2.39E+01)	8.74E+02(2.62E+01)	3.96E+02 (1.29E+01)	8.35E+02(3.77E+01)	7.95E+02(3.00E+01)
F29	7.66E+02(2.14E+02)	5.83E+02(2.03E+02)	1.08E+03(2.20E+02)	2.14E+02 (1.31E+00)	6.84E+02(1.33E+02)	6.73E+02(1.51E+02)
F30	1.29E+03(3.69E+02)	1.15E+03(1.31E+02)	1.51E+03(5.32E+02)	5.36E+02 (1.38E+02)	7.62E+02(3.87E+02)	6.75E+02(3.58E+02)
	14/9/7	29/0/1	25/4/1	21/4/5	13/11/6	+/-/=

Algorithm 3 Adaptive Local search for P_{main} .

- 1) **if** $LST == 1$
 - a) Sort P_{main} according to fitness value order.
 - b) Perform a local Cauchy search on the top 2% to increase the diversity of P_{main} .
 - c) Replace the old individuals with new outstanding individuals.
- 2) **else if**
 - a) Perform a Gaussian local search on the best individual of P_{main} .
 - b) Replace the old individuals with new outstanding individuals.
- 3) **end if**

space is $[-100,100]^D$. The dimensions of benchmark functions are $D = 30$ and 100 . The values of the optimal solutions are known in advance for all benchmark functions. The maximum number of objective function evaluations is $D \times 10,000$. The parameter settings of AMMADE are listed in Table I, and the control parameters of other algorithms are set as suggested in the corresponding papers.

B. Exploring the Proposed Strategies

In this section, we explore the proposed strategies by comparing AMMADE with MPEDE and its variant: MPEDE, which uses random sorting mutation strategy and reward population strategy. AMMADE_1, which uses adaptive mutation operator strategy based on multi-population and AMMADE uses adaptive mutation operator strategy based on multi-population and adaptive local search strategy.

TABLE IV: COMPARISON OF RESULTS IN TERMS OF MEAN (STD) ON THE CEC2014 TEST FUNCTIONS WITH D=100

	JADE	CoDE	SaDE	EPSDE	MPEDE	AMMADE
Functions	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)
F1	1.82E+05 (5.94E+04)	7.04E+06(2.01E+06)	6.84E+06(1.91E+06)	3.19E+05(1.21E+05)	2.67E+05(1.05E+05)	2.92E+05(1.14E+05)
F2	3.80E-03(1.05E-02)	1.68E+03(9.97E+02)	2.99E+04(6.90E+03)	4.36E+03(2.09E+04)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F3	5.08E+03(4.66E+03)	6.33E+01(6.83E+01)	8.94E+01(9.74E+01)	1.40E-02 (4.55E-02)	7.23E+02(8.01E+02)	9.97E+02(1.03E+03)
F4	1.38E+02(4.75E+01)	1.68E+02(2.77E+01)	3.80E+02(3.66E+01)	1.41E+02(4.35E+01)	9.46E+01(5.73E+01)	8.25E+01 (5.79E+01)
F5	2.04E+01 (1.40E-01)	2.12E+01(2.78E-02)	2.10E+01(2.79E-02)	2.11E+01(4.77E-02)	2.08E+01(8.48E-02)	2.07E+01(9.86E-02)
F6	4.65E+01(1.46E+01)	1.72E+01(4.35E+00)	8.92E+01(2.73E+01)	1.31E+02(4.40E+00)	4.32E+01 (4.81E+00)	4.34E+01 (7.02E+00)
F7	4.29E-03 (9.45E-03)	3.31E-07(2.31E-07)	6.39E-02(2.53E-02)	4.78E-03(8.88E-03)	1.74E-03 (4.73E-03)	1.59E-03 (4.48E-03)
F8	0.00E+00 (0.00E+00)	3.41E+02(1.64E+01)	2.93E+02(1.05E+01)	9.12E+01(1.39E-01)	2.15E-01(5.38E-01)	5.07E-01(1.17E+00)
F9	1.56E+02 (1.88E+01)	4.81E+02(1.83E+02)	7.43E+02(2.06E+01)	6.43E+02(4.47E+01)	1.56E+02 (2.15E+01)	1.59E+02 (2.52E+01)
F10	1.04E-02 (7.14E-03)	1.22E+04(6.22E+02)	1.06E+04(4.33E+02)	1.03E+04(1.94E+03)	7.04E-01(5.02E-01)	3.37E+00(1.87E+00)
F11	1.07E+04 (5.05E+02)	2.65E+04(7.20E+02)	2.37E+04(4.71E+02)	2.67E+04(1.27E+03)	1.13E+04(1.11E+03)	1.12E+04(9.75E+02)
F12	3.35E-01 (2.53E-02)	2.68E+00(1.46E-01)	1.91E+00(1.24E-01)	1.96E+00(1.67E-01)	7.72E-01(1.64E-01)	4.51E-01(1.54E-01)
F13	4.07E-01(4.56E-02)	6.00E-01(4.58E-02)	4.52E-01(2.48E-02)	4.80E-01(5.83E-02)	3.67E-01 (3.84E-02)	3.66E-01 (3.92E-02)
F14	3.08E-01 (2.25E-02)	3.55E-01(2.41E-02)	3.09E-01 (1.26E-02)	3.34E-01(3.16E-02)	3.02E-01 (2.16E-02)	3.01E-01 (2.47E-02)
F15	3.57E+01(5.73E+00)	6.67E+01(3.42E+00)	7.14E+01(5.23E+00)	9.15E+01(1.44E+01)	1.76E+01 (2.78E+00)	1.81E+01 (3.59E+00)
F16	3.99E+01(5.92E-01)	4.57E+01(2.87E-01)	4.44E+01(3.03E-01)	4.59E+01(5.46E-01)	4.04E+01(6.95E-01)	3.94E+01 (1.09E+00)
F17	2.50E+04(8.01E+03)	2.97E+05(1.40E+05)	1.40E+04 (5.01E+03)	4.48E+06(8.83E+06)	2.15E+04(1.04E+04)	2.66E+04(9.90E+03)
F18	1.02E+03(9.35E+02)	5.11E+02(5.34E+02)	4.24E+02(2.87E+02)	3.93E+03(5.28E+03)	2.84E+02 (4.22E+01)	2.81E+02 (8.76E+01)
F19	9.44E+01(2.11E+01)	9.47E+01(1.30E+00)	7.48E+01(2.36E+01)	5.56E+01 (2.53E+01)	9.33E+01(2.15E+01)	9.63E+01(8.44E+00)
F20	5.85E+03(1.27E+04)	2.69E+02(1.12E+02)	2.62E+02 (5.56E+01)	1.43E+03(4.50E+03)	4.91E+02(1.52E+02)	5.97E+02(3.05E+02)
F21	7.87E+03(3.70E+03)	7.53E+04(4.61E+04)	2.88E+03 (1.23E+03)	3.62E+05(2.29E+05)	4.84E+03(2.43E+03)	6.91E+03(4.09E+03)
F22	1.53E+03(2.28E+02)	2.01E+03(5.13E+02)	2.63E+03(1.91E+02)	2.16E+03(3.67E+02)	1.70E+03(4.20E+02)	1.64E+03 (4.32E+02)
F23	3.48E+02(1.96E-11)	3.48E+02(4.14E-07)	3.48E+02(1.03E-01)	3.45E+02 (9.19E-13)	3.48E+02(0.00E+00)	3.48E+02(9.19E-13)
F24	3.97E+02(4.86E+00)	3.68E+02(3.26E+00)	3.71E+02(3.38E+00)	4.07E+02(8.30E+00)	3.96E+02(5.43E+00)	3.91E+02 (4.40E+00)
F25	2.69E+02(7.65E+00)	2.03E+02(7.96E-01)	2.00E+02(6.74E-04)	2.59E+02(3.31E+01)	2.15E+02(2.12E+01)	2.02E+02 (8.49E+00)
F26	2.00E+02(1.89E-02)	1.92E+02(2.70E+01)	2.00E+02(1.31E-02)	1.40E+02 (5.04E+01)	1.98E+02(1.40E+01)	1.98E+02(1.40E+01)
F27	1.12E+03(1.29E+02)	4.79E+02(5.65E+01)	7.89E+02(5.68E+01)	3.76E+03(6.07E+01)	1.14E+03(1.12E+02)	9.54E+02 (1.17E+02)
F28	2.39E+03(2.73E+02)	2.69E+03(2.58E+02)	8.80E+03(9.07E+02)	8.68E+02 (2.79E+02)	2.31E+03(2.60E+02)	2.43E+03(4.32E+02)
F29	1.37E+03(8.84E+01)	1.97E+03(1.45E+02)	2.06E+03(2.22E+02)	2.64E+02 (2.56E+01)	1.05E+03(2.22E+02)	1.22E+03(2.18E+02)
F30	8.42E+03(1.19E+03)	5.49E+03(1.16E+03)	6.79E+03(1.62E+03)	2.60E+03 (3.81E+02)	7.08E+03(1.46E+03)	7.13E+03(1.10E+03)
	14/9/7	22/1/7	21/2/7	21/2/7	8/17/5	+/-/=

The Nonparametric Wilcoxon rank-sum test at a 0.05 significance level has been performed between AMMADE and each algorithm to be compared on each benchmark function. The sign ‘+’ in the results indicates the performance of AMMADE is significantly better than the corresponding algorithm, ‘-’ vice versa and ‘=’ denotes there is no significant difference between the performance.

The results (error values $f - f^*$) on 30 dimensions are shown in Table II, which f^* is the best fitness value. From the results, we can see that among the 30 benchmark functions, AMMADE achieves the best mean values on 23 functions. The AMMADE results are significantly better than the other two algorithms. It can be seen from the results that the strategies proposed are effective.

C. Comparisons with Related Algorithms

In this section, we compared AMMADE to the following five DE variants:

- 1) JADE [5]: DE with adaptive control parameters and optional external archive;
- 2) CoDE [6]: DE with composite trial vector generation strategies and control parameters;
- 3) SaDE [7]: DE with strategy adaptation;
- 4) EPSDE [4]: DE with ensemble of parameters and mutation strategies;
- 5) MPEDE [9]: DE with multi-population based ensemble of mutation strategies.

Table III and IV show the comparison results (error values $f - f^*$) of the six algorithms. From Table III on 30D and 100D optimization, respectively. By analyzing the experimental results from 30D, conclusions are given as follows.

Firstly, for uni-modal functions F1–F3, MPEDE show the best performance on F1, and AMMADE is also competitive compared to other algorithms on F1. For F2, several related algorithms except CoDE can find the optimal value. For F3, only EPSDE, MPEDE and AMMADE can find the optimal value. Secondly, for basic multi-modal benchmark functions F4-F16, JADE performed the best, achieving the best mean fitness on 11 functions (F4-F5, F7-F8, F10-F16). AMMADE's performance is also quite competitive, with excellent performance on 7 functions (F5, F7-F9, F13-F15). Thirdly, for the hybrid functions F17-F22, the best performer is MPEDE, which has the best mean fitness on 5 functions (F17,F19-F22). AMMADE performs well on 4 functions (F17-F19, F23). This can reflect that AMMADE is also competitive for hybrid functions. Finally, for the complex composition functions F23-F30, EPSDE achieves the best results. AMMADE, MPEDE and JADE perform well on 2 functions (F24,F26), one function (F26) and two functions (F26-F27), respectively. Based on the experimental results and analysis on the CEC2014 test suit, we can see that AMMADE is competitive on various functions with related algorithms.

V. CONCLUSIONS

In this paper, we propose a multi population based DE with adaptive mutation and local search for global optimization. In the proposed method, at each stage, the proposed grouping and sorting method is used to partition the population. Individuals then will use different mutation strategies in different subpopulation according to the ranking of Euclidean distance. In addition, an adaptive local search strategy is proposed, in which different local search strategies will be dynamically employed to improve the solution at different stages. The experimental results clearly show the merits of the proposed strategies and the resulting method could outperform the related methods to be compared.

REFERENCES

- [1] K. M. Sallam, S. M. Elsayed, R. K. Chakraborty, and M. Ryan, "Evolutionary framework with reinforcement learning-based mutation adaptation," *IEEE Access*, vol. 8, 2020.
- [2] X. F. Liu, Z. H. Zhan, Y. Lin, W. N. Chen, Y. J. Gong, T. L. Gu, H. Q. Yuan, and J. Zhang, "Historical and heuristic-based adaptive differential evolution," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. PP, pp. 1–13, 2018.
- [3] S. Kitayama, M. Arakawa, and K. Yamazaki, "Differential evolution as the global optimization technique and its application to structural optimization," *Applied Soft Computing*, vol. 11, no. 4, pp. 3792–3803, 2011.
- [4] R. Mallipeddi and P. N. Suganthan, "Differential evolution algorithm with ensemble of parameters and mutation and crossover strategies," in *Swarm, Evolutionary, and Memetic Computing - First International Conference on Swarm, Evolutionary, and Memetic Computing, SEM-CCO 2010, Chennai, India, December 16-18, 2010. Proceedings*, 2010.
- [5] J. Zhang and A. C. Sanderson, "Jade: adaptive differential evolution with optional external archive," *IEEE Transactions on evolutionary computation*, vol. 13, no. 5, pp. 945–958, 2009.
- [6] W. Yong, Z. Cai, and Q. Zhang, "Differential evolution with composite trial vector generation strategies and control parameters," *IEEE Transactions on Evolutionary Computation*, vol. 15, no. 1, pp. 55–66, 2011.
- [7] A. K. Qin and P. N. Suganthan, "Self-adaptive differential evolution algorithm for numerical optimization," in *IEEE Congress on Evolutionary Computation*, 2005.
- [8] X. Li, L. Wang, Q. Jiang, and N. Li, "Differential evolution algorithm with multi-population cooperation and multi-strategy integration," *Neurocomputing*, vol. 421, no. 1, pp. 285–302, 2021.
- [9] G. Wu, R. Mallipeddi, P. N. Suganthan, W. Rui, and H. Chen, "Differential evolution with multi-population based ensemble of mutation strategies," *Information Sciences An International Journal*, vol. 329, no. C, pp. 329–345, 2016.
- [10] M. M. Mafarja and S. Mirjalili, "Hybrid whale optimization algorithm with simulated annealing for feature selection," *Neurocomputing*, vol. 260, pp. 302–312, 2017. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S092523121730807X>
- [11] T. Rogalsky and R. W. Derksen, "Hybridization of differential evolution for aerodynamic design," 2000.
- [12] D. Molina, A. Latorre, and F. Herrera, "Shade with iterative local search for large-scale global optimization," in *2018 IEEE Congress on Evolutionary Computation (CEC)*, 2018.
- [13] R. Tanabe and A. Fukunaga, "Evaluating the performance of shade on cec 2013 benchmark problems," in *2013 IEEE Congress on evolutionary computation*. IEEE, 2013, pp. 1952–1959.
- [14] J. Brito, L. Ochi, F. Montenegro, and N. Maculan, "An iterative local search approach applied to the optimal stratification problem," *International Transactions in Operational Research*, vol. 17, no. 6, pp. 753–764, 2010.
- [15] X. Wang, M. Sheng, K. Ye, J. Lin, J. Mao, S. Chen, and W. Sheng, "A multilevel sampling strategy based memetic differential evolution for multimodal optimization," *Neurocomputing*, vol. 334, no. MAR.21, pp. 79–88, 2019.

Compact Dual-band 4-MIMO Antenna Elements for 5G Mobile Applications

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Abstract

The significance of the Multiple Input Multiple Output (MIMO) system in the 5G wireless communication system is essential to enhance channel capacity and provide a high data rate resulting in a need for dual-polarization in vertical and horizontal. Furthermore, size reduction is critical in a MIMO system to deploy more antenna elements requiring a compact, low-profile design. A compact dual-band 4-MIMO antenna system has been presented in this paper with pattern and polarization diversity. The proposed single antenna structure has been designed using two antenna layers with a C shape in the front layer and a partial slot with a U-shaped cut in the ground to enhance isolation. The single antenna is printed on an FR4 dielectric substrate with an overall size of 18 mm×18 mm×1.6 mm. The 4-MIMO antenna elements were printed orthogonally on an FR4 substrate with a size dimension of 36 × 36 × 1.6 mm³ with zero edge-to-edge separation distance. The proposed compact 4-MIMO antenna elements resonate at 3.4-3.6 GHz and 4.8-5 GHz. The s-parameters measurement and simulation results agree, especially in the lower band with a slight frequency shift of the measurement results at the upper band due to fabrication imperfection. The proposed design shows isolation above -15 dB and -22 dB across the 4-MIMO elements. The MIMO diversity performance has been evaluated in terms of efficiency, ECC, DG, TARC, and CCL. The total and radiation efficiency were above 50 % across all parameters in both frequency bands. The ECC values were lower than 0.10, and the DG results were about 9.95 dB in all antenna elements. TARC results exhibited values lower than 0 dB with values lower than -25 dB in all MIMO elements at the dual-bands. Moreover, the channel capacity losses in the MIMO system were depicted using CCL with values lower than 0.4 Bits/s/Hz.

Keywords

Compact antennas; MIMO antenna system; 5G communication; dual band; ECC; DG; TARC.

Experimental Study of the Influence of Clumped Weights on a Scaled Mooring Line

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Abstract— Floating wind power is considered one of the most promising sources of sustainable energy today and considered as a key technology in meeting decarbonization objectives. The atmospheric conditions that are found in deep water places are more profitable in comparison with coastal areas, as consequence there is a clear tendency of placing Floating Offshore Wind Turbines (FOWT) in deeper waters. However, in order to install more offshore farms where better atmospheric conditions are found, highly reliable mooring solutions are required. Important research was performed by Azcona in [1], where a computational study of the dynamics of a mooring line including experimental validation was performed. Recently, Bruschi et al. [2] studied numerically the advantages of adding clumped weights at discrete positions of the mooring line. In our case, in order to confirm the influence of this weights an experimental study of a 1:31 scaled model of a mooring line was performed. In this study the clumped weight is represented by an scaled cylinder placed at different positions along the mooring line. The series of experiments have been carried out at CEHIPAR towing tank for a submerged studless chain with and without the clumped weights. The experiments consist on the excitation of the suspension point (fairlead) with horizontal periodic motions using different amplitudes and periods. The chain's tension is measured at the fairlead and the motion of part of the chain is also recorded using submerged cameras. Similarly to previous validations, see [1], the novelty of the presence of clumped weights provides new experimental data for future discussions and validation of numerical codes.

Keywords— mooring lines, floating offshore, clumped weights, hybrid mooring system, wind energy.

Graphene-Based Nanocomposites as Ecofriendly Antifouling Surfaces

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Abstract:

After the prohibition of tin-based fouling-prevention coatings in 2003, the researchers were directed toward eco-friendly coatings. Because of their nonstick, environmental, and economic benefits, foul-release nanocoatings have received a lot of attention. They use physical anti-adhesion terminology to deter any fouling attachment. Natural bioinspired surfaces have micro/nano-roughness and low surface free energy features, which may inspire the design of dynamic antifouling coatings. Graphene-based nanocomposite surfaces were designed to combat marine-fouling adhesion with ecological as well as eco-friendly effects, rather than biocidal solutions. Polymer-graphene nanofiller hybrids are a novel class of composite materials in fouling-prevention applications. The controlled preparation of nanoscale orientation, arrangement, and direction along the composite building blocks would result in superior fouling prohibition. This work represents foul-release nanocomposite top coats for marine coating applications with superhydrophobicity, surface inertness against fouling adherence, cost-effectiveness, and increased lifetime.

Keywords: *Foul-release nanocoatings, Graphene-based nanocomposite, polymer, nanofillers*

Economic and Environmental Impact of the Missouri Grazing Schools

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Abstract— Management-intensive Grazing (MiG) is a practice that rotates livestock through paddocks in a way that best matches the nutrient requirements of the animal to the yield and quality of the pasture. In the USA, MiG has been taught to livestock producers throughout the state of Missouri in 2- and 3-day workshops called “Missouri Grazing Schools.” The economic impact of these schools was quantified using IMPLAN software. The model included hectares of adoption, animal performance, carrying capacity, and input costs. To date, MiG as taught in the Missouri Grazing Schools has been implemented on more than 70,000 hectares in Missouri. The economic impact of these schools is presently \$125 million USD per year added to the state economy. This magnitude of impact is the result not only of widespread adoption, but also because of increased livestock carrying capacity; in Missouri, a capacity increase of 25 to 30% has been well documented.

Additional impacts have been MiG improving forage quality and reducing cost of feed and fertilizer. The environmental impact of MiG in the state of Missouri is currently being estimated. Environmental impact takes into account the reduction in application of commercial fertilizers; in MiG systems, nitrogen is supplied by N fixation from legumes, and much of the P and K is recycled naturally by well-distributed manure. Environmental impact also estimates carbon sequestration and methane production; MiG can increase carbon sequestration and reduce methane production in comparison to default grazing practices and feedlot operations in the USA.

Keywords— agricultural education, forage quality, management-intensive grazing, nutrient cycling, stock density, sustainable agriculture

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The Healing Effect of Chitosan Supported nano-CeO₂ on Experimental Excisional Wound Infected with *Pseudomonas aeruginosa* in Rat

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Abstract— The chitosan supported nano-CeO₂ hydrogel was prepared and characterized using Fouriertransform infrared spectroscopy (FT-IR), Energy Dispersive X-ray Spectroscopy (EDX), X-ray powder diffraction (XRD), Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). The wound was infected with *p. aeruginosa* and in positive control (PC) group it was treated with silver sulfadiazine ointment with no treatment in negative control (NC) group. The infected wound was treated with chitosan suspension-gel, cerium oxide nanoparticles solution or chitosan supported-CeO₂ nanoparticle gel in the treatment groups. The rats were randomized into five groups (n=12). Each group was subdivided into three subgroups of four animals each and studied 3, 7 and 14 days post-wounding. Results-Plantimetry, histopathological assessments and hydroxyprolin content showed better and faster healing of the wounds in the treatment groups, particularly in chitosan supported-CeO₂ nanoparticle gel (ChCe) group compared to the NC group (P< 0.05). Using by Ferric Reducing Antioxidant Power (FRAP) the total antioxidant capacity was statistically higher in treatment groups compared to NC group (p< 0.05). The bacterial numbers were significantly lower in ChCe and cerium oxide nanoparticles solution (Ce) groups compared to chitosan (CH) group on day 3 post-wounding (P< 0.05). Conclusion and Clinical Relevance-Topical application of the chitosan supported nano-CeO₂ particles on the infected wound enhanced tissue total antioxidant capacity, reduced the bacterial count, accelerated proliferation and migration of fibroblasts and keratinocytes, increased hydroxyproline level and neovascularization scale of the healing wound. Chitosan supported nano-CeO₂ hydrogel could be suggested as an alternative therapy for treating of the infected wound.

Keywords— nano-CeO₂, chitosan, *pseudomonas aeruginosa*, wound healing, rat.

Broad Survey of Fine Root Traits to Investigate the Root Economic Spectrum Hypothesis and Plant-Fire Dynamics Worldwide

Jacob L. Watts, Adam F. A. Pellegrini

Abstract—Prairies, grasslands, and forests cover an expansive portion of the world's surface and contribute significantly to Earth's carbon cycle. The largest driver of carbon dynamics in some of these ecosystems is fire. As the global climate changes, most fire-dominated ecosystems will experience increased fire frequency and intensity, leading to increased carbon flux into the atmosphere and soil nutrient depletion. The plant communities associated with different fire regimes are important for reassimilation of carbon lost during fire and soil recovery. More frequent fires promote conservative plant functional traits aboveground; however, belowground fine root traits are poorly explored and arguably more important drivers of ecosystem function as the primary interface between the soil and plant. The root economic spectrum (RES) hypothesis describes single-dimensional covariation between important fine-root traits along a range of plant strategies from acquisitive to conservative – parallel to the well-established leaf economic spectrum (LES). However, because of the paucity of root trait data, the complex nature of the rhizosphere, and the phylogenetic conservatism of root traits, it is unknown whether the RES hypothesis accurately describes plant nutrient and water acquisition strategies. This project utilizes plants grown in common garden conditions in the Cambridge University Botanic Garden and a meta-analysis of long-term fire manipulation experiments to examine the belowground physiological traits of fire-adapted and non-fire-adapted herbaceous species to 1) test the RES hypothesis, and 2) describe the effect of fire regimes on fine root functional traits – which in turn affect carbon and nutrient cycling. A suite of morphological, chemical, and biological root traits (e.g. root diameter, specific root length, percent N, percent mycorrhizal colonization, etc.) of 50 herbaceous species were measured and tested for phylogenetic conservatism and RES dimensionality. Fire-adapted and non-fire-adapted plants traits were compared using phylogenetic PCA techniques. Preliminary evidence suggests that phylogenetic conservatism may weaken the single-dimensionality of the RES suggesting that there may not be a single way that plants optimize nutrient and water acquisition and storage in the complex rhizosphere; additionally, fire-adapted species are expected to be more conservative than non-fire-adapted species, which may be indicative of slower carbon cycling with increasing fire frequency and intensity.

Keywords—climate change, fine roots, fire regimes, root economic spectrum

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Germplasm collections and Morphological studies of *Andropogon gayanus-Andropogon tectorum* Complex in Southwestern Nigeria

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Abstract

Morphological studies were carried out on *Andropogon gayanus-Andropogon tectorum* complex collected in Southwestern Nigeria to provide full characterization of the two species of *Andropogon*; elucidating their population dynamics. Morphological data from selected accessions of *A. gayanus* and *A. tectorum* from different parts of Southwestern Nigeria were collected and characterized using an adaptation of the *Descriptors for Wild and Cultivated Rice (Oryza spp)*. Preliminary morphological descriptions were carried out at the points of collection. Garden populations were raised from the vegetative parts of some accessions and hybrids were maintained in Botanical Garden of the Obafemi Awolowo University, Ile-Ife. The data obtained were subjected to inferential tests and Duncan's multiple range test. This study has revealed distribution pattern of the two species in the area of study which suggests a south-ward migration of *Andropogon gayanus* from the northern vegetational zones of Nigeria to the southern ecological zones. The migration of *A. gayanus* around Igbeti with occasional occurrence of *A. tectorum* along the roadsides without any distinct phenotypic hybrid, and Budo-Ode in Oyo State has been established as the southern limit of the spread of *A. gayanus*, the migration of *A. gayanus* to the South is not an invasion but a slow process. *A. gayanus* was not encountered in Osun, Ondo, Ekiti and Ogun States. *Andropogon gayanus* and *Andropogon tectorum* not only emerge from the rootstocks rapidly but can also produce independent propagules by rooting at some nodes. The plants can spread by means of these propagules even if it does not produce sexual or apomictic seeds. This potential for vegetative propagation in addition to the perennial habit confer considerable advantage for colonization by the *Andropogon gayanus-Andropogon tectorum* Complex.

Keywords: Accessions, Apomictic, distribution, migration, propagation.

Biopesticide Properties of Three Botanicals (*Ageratum Conyzoides*, *Petiveria Alliacea* and *Hyptis Suaveolens*) Against *Sitophilus Oryzae* and *Oryzaephilus Surinamensis*

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ABSTRACT

The record of food poison as a result of contamination from pesticide residue used in food preservation. Various methods and alternatives have been assessed which is safe for human and other animals. Plant related products are safe for the consumption due to their ecofriendly and biodegradable properties. In this research *Ageratum conyzoides*, *Petiveria alliacea* and *Hyptis suaveolens* against *Sitophilus oryzae* and *Oryzaephilus surinamensis* were used in the control of the infestation of *Sitophilus oryzae* and *Oryzaephilus surinamensis*. At 0.5 concentration 6.67% mortality was recorded in all the botanicals at 24hrs. The values were no significantly different from one another ($p < 0.05$) and the control. As the time increase to 48hrs the following values were recorded: *A. conyzoides* (13.33%), *P. alliacea* (13.33%) and *H. suaveolens* (26.67%). As the concentration of the botanical and exposure time increase the mortality increase. For 2.5% concentration, at 24hrs *Ageratum conyzoides* have 20.00%, *Petiveria alliacea* (10.00%) and *Hyptis suaveolens* (33.33%) mortality of *Oryzaephilus surinamensis*. There is no statistically significant difference among the value *A. conyzoides*, *P. alliacea* and the control but there is a significant difference the mortality recorded on the treatment of *H. suaveolens*, *P. alliacea* and the control. At 48hours *A. conyzoides* have 26.67.00%, *P. alliacea* (26.67%) and *H. suaveolens* (60.00%) mortality of *Oryzaephilus surinamensis*. The value of *H. suaveolens* shows a significant difference from the control while other control is not significant different from the

control. At 72hrs *A. conyzoide* have 36.67%, *P. alliacea* (43.33%) and *H. suaveolens* (73.33%) mortality of *Oryzaephilus surinamensis*. The value of *H. suaveolens* was significantly different from that of the control and other two botanicals. At 96hours, 60.00% mortality of *O. surinamensis* was recorded on *A. conyzoide*, 66.67% on *P. alliacea* while 100.00% mortality was recorded on *H. suaveolens*. There is a significant difference in the value recorded on *H. suaveolens* and other botanicals with the control. At 120hrs with the same concentration (2.5%), 80% mortality of *O. surinamensis* on *A. conyzoide*, 80% was recorded on *P. alliacea* while 100.00% mortality was recorded on *H. suaveolens*. The value from the three botanical *A. conyzoide*, *P. alliacea* and *H. suaveolens* was significantly different from the control. *H. suaveolens* showed the highest mortality of *O. surinamensis* at concentration of 2.5% and 120hrs, although the value increase as the time of exposure increases.

Keywords: Botanicals, *Sitophilus oryzae*, *Oryzaephilus surinamensis*, *Ageratum conyzoide*, *Petiveria alliacea* and *Hyptis suaveolens*

Introduction

Apart from terrorist attacks that are putting threats on many continents including Sahara Africa, food insecurity is another major issue. Many countries and their citizen were not able to produce process and preserve enough food that is needed for the healthy growth of their citizen, both young and old. Rice is one the staple food and the second most consumed cereal in the world (FAO, 2011). According to FAO 2004, rice gives about 20% of the world total energy supply followed by the wheat 19% and maize 5%. More than 17 countries in Asia and the pacific, 8 countries in Africa and 9 countries in South and North America depends on rice as a major dietary source. Gross increase in Africa population also called for increase in rice production in Africa and sub -Sahara Africa (WARDA, 2008). Many countries in Africa and Sub Sahara Africa import rice in which Nigeria is one of them (WARDA 2007). Various attack has been reported facing rice from planting to processing and to storage and preservation. Insects are major threat to rice production; this may be as a result of insect competing with man on the nutritional benefit of the rice. Some of these insect pests are primary pest while some are secondary. *Sitophilus oryzae* (Linn), *Callosobruchus maculatus*, *Oryzaephilus surinamensis* are examples of some insect that attack that attack rice. For *Sitophilus oryzae*, the larva and adult cause damage to the rice grain. Adult *Sitophilus oryzae* are active fliers that could fly to the farm and attack the grain on the field before harvest in tropic. *Sitophilus oryzae* larva is known to cause between 25% to 100% loss in the stored grains (Akunne *et al.*, 2013). Apart from direct loss caused by the insect, they also reduce seed viability, reduce market values, nutritional content and bring about unpleasant smell (Ashamo and Ogungbite 2014) .Various approach has been given to control and management of these stored insect pest like *Sitophilus oryzae* and *Oryzaephilus surinamensis* ranging from the use of chemicals to botanical and other physical methods. Host resistance is another potential solution to the stored product pest damages since various rice cultivars has various levels of resisting *Sitophilus oryzae* and *Oryzaephilus surinamensis* and other stored product insect pest (Ashamo *et al.*, 2013). A lot of work has been carried out by various on susceptibility of rice to *Sitophilus oryzae* and *Oryzaephilus surinamensis*. Nevertheless, a lot local cultivars have not been assessed against *Sitophilus oryzae* and *Oryzaephilus surinamensis* susceptibility. This

work is focused on resistance or susceptibility of eleven local rice cultivars in South west Nigeria to *Sitophilus oryzae* and *Oryzaephilus surinamensis* under the laboratory control. Rice is a known staple food for more than 60% of the total population. It is highly rich in nutritional values such as carbohydrate, protein, fibre, fat and others. Rice is well familiar with by old and young in the community. Many stored product insects get their nourishment from rice like other rich substrates. Rice weevil – *Sitophilus oryzae* (Coleoptera: Curculionidae). This is one of the serious pests of rice, wheat, millet, barley, maize, sorghum and other cereals causing considerable qualitative and quantitative loss during the storage. Hot and humid climate favour its development. It is one of the cosmopolitan pests, and both larvae and adult stages cause economic damage. Adult is a tiny weevil of about 2.5 mm long and dark brown or reddish brown. Head protrudes into a cylindrical rostrum formed into a snout with strong pair of jaws at the distal end and prominent antennae emerging from the base of rostrum. Apparently two sexes are alike but rostrum is short and broader in males. In case of heavy infestation, only pericarp of the kernel is left behind, while rest of the mass is eaten up. This pest can also infest cereal crops at maturing stage in the field. Female starts laying eggs after 4-5 d of the emergence and 300-400 eggs are laid by each individual. Eggs are translucent and white measured 0.7mm long and 0.3mm broad. Female makes a slit like opening with mandibles and rostrum in sprout part of the grain to lay egg in the hole and plug it with secreted material from the ovipositor. Eggs hatch in about four to five days under hot and humid weather but might take six to nine days during cooler months. The newly hatched grub bores into the kernel of the grain. Grubs are white, curved, and translucent, with yellow or brown head and biting jaws. As soon as it emerges from egg, it starts feeding on the starchy material of the seeds, till it becomes fully grown and leaves behind only an intact pericarp shell filled with frass. The grub stage lasts for 19-34days and then pupates to a non-feeding pupal stage after passing 2-3days as prepupa. Pupal period lasts for one week and the adult emerging out of grain is at once ready for breeding. Grain with emergence hole becomes quite hollow and can float in water. This pest completes its life cycle within a month at $28\pm 1^{\circ}\text{C}$ and 70% RH. Severely damaged lots of grains resemble mouldy grains. The rice weevil is one of the most important destructive primary pests attacking many common stored cereals and has a worldwide distribution (Park *et al.*, 2003). Stored and milled rice grains are prone to attack by *Sitophilus oryzae* and the latter grains are mostly preferred causing heavy economic losses and both the adults and larvae feed on the carbohydrates in rice grains causing weight loss and contamination (Ashamo & Odeyemi, 2001). In absence of control, the stored grains can be destroyed even up to 100% (Park *et al.*, 2003). Enhancing the temperature and humidity of the infested grains, *S. oryzae* activity also induces accelerated growth of the secondary pests and creates most favourable conditions for pathogens and further infestation (Park *et al.*, 2003). Huge loss is recorded with all the four larval stages and adults and all the biological stages (egg, larva, pupa and adult) occur inside the grains, the study on the biology of the pest was undertaken. Saw toothed grain beetle *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) This is generally associated with starchy food and found in warm places. Common name is due to its peculiar structure of thorax which bears six teeth like projections on each side. It is a cosmopolitan pest of stored grain and grain products and reported to occurs in flour mills, warehouses, glossary stores, etc. Generally, beetles live from six to ten months.

Female lays six to ten eggs per day and 50 to 300 small and white eggs in her life span, loosely in food medium or in cracks and crevices. Larvae moult three times generally. Adults live 6 to 8 months but die in dust free undamaged grain. Larvae feed on endosperm of broken grains or starchy food.

Ageratum conyzoides has bioactivity that may have agricultural use. The crude plant extract also showed insecticidal and pesticidal activities against various types of insects and pests. The major components of the oil, namely the precocenes, have been reported to have antijvenile hormonal activity. The oil exerted acute toxicity on adults of cowpea weevil, *Callosobruchus maculatus* F., upon fumigation. Application of oil dressing on cowpea seed exhibited insecticidal activity against weevil. Significant oviposition deterrence and complete inhibition of emergence of adult insects F1 offspring from oil-treated beans were evident at 2.5-10 μ l/9.5 g beans with no adverse physiological effect. Precocene I was found to be four times as active as the oil. Assays conducted in India showed high nymphal mortality 91 % of the oil to the Nymphs of *S. gregaria* (Singh *et al.*, 2014). showed that the hexane extract of the whole plant showed activity against *M. domestica* larvae. Methanolic extract from fresh leaves (250 and 500 ppm) also produced deficiency of juvenile hormone in the fourth instar of *C. partellus*, a sorghum pest. Anti-juvenile hormonal activity of Precocenes I and II have been demonstrated on a variety of insects, which include *S. oryzae*, *T. japonica*, *L. chinensis* and *D. β avidus*. The results from these assays include precocious metamorphosis of the larvae, production of sterile, moribund and dwarfish adults. The two chromenes have been reported to act synergistically and they survived metabolism for at least 12 days. Preliminary study on the mode of action of precocene II on *M. domestica* L. and *L. caesar* L. has been carried out. While the precocenes have been seen as fourth-generation insecticides, the drawback is that they have been shown to cause hepatotoxicity in rats. This is an important factor bearing in mind the human health hazard in field applications of precocenes as large-scale insecticidal agents. Some workers demonstrated that the toxicity was due to a highly reactive precocene- 3, 4-epoxide, a metabolite produced in insect species from cytochrome P-450. The insecticidal activities of hexane and ethanol extract were evaluated against adults of *R. dominica*. Only the hexane extract showed insecticidal activity. 5, 6, 7, 8, 3', 4', 5'-Hepta methoxy β avone showed low activity against *D. hyalinata* and *R. dominica* and was not toxic to *M. domestica* or *P. americana*. In contrast, coumarone showed insecticidal activity against all four insect and pest species tested. The extract of the plant was found to exhibit juvenile effect on *D. cingulatus* nymphs. The alcoholic extract of the plant possessed insecticidal activity against *M. domestica* and *T. castaneum*. The petroleum ether and acetone extract of the plant showed juvenile hormone activity against *C. quinquefasciatus*, *A. aegypti* and *A. stephensi*. The methanolic extract of the plant was found to suppress the population of the malaria vector *A. stephensi* in higher dosage, whereas in lower dosage it was found to induce several developmental defects and ultimately decrease the growth index to a considerable extent. In another study, higher concentrations of the crude extract suppressed the vector population of *C. quinquefasciatus*, whereas the lower concentrations were found to induce developmental defects ultimately decreasing the growth index of the treated second and fourth instar larvae. The petroleum ether extract of the leaves, flowers and buds diluted in benzene and mixed with green gram seeds

proved very repulsive, a potent oviposition inhibitor and a safe protectant against the infestation of pulse beetle *C. chinensis* (Ogungbite and Oyeniya 2014). The crude extract of the plant showed insecticidal activity against nymphs of mustard aphid *L. erysimi* (Kamboj and Saluja, 2008). In Mexico, there are several plants with insecticidal properties; among these, *Petiveria alliacea* L. (Phytolaccaceae), native to the Caribbean, Central and South America (Ashamo 2006), is commonly known in Mexico as mapurite or hierba del zorrillo, because of the unpleasant odor produced by its leaves, which contain sulfide compounds (Singh *et al.*, 2014). These compounds are believed to have insecticidal activity against the adult insects *Cimex lectularius* and *Musca domestica*, it repels termites and acts as an acaricide and nematicide against *Meloidogyne* spp. (Ashamo, *et al.*, 2013).

Hyptis suaveolens (L.) Poit, a potential anti-feedant plant product belongs to the family laminaceae Ethnobotanical studies conducted in Kenya on *H. suaveolens* showed that, the plant can repel mosquitoes effectively when burned overnight in rooms and also in his phytochemical and Ethnobotanical database refers to the plant as insect repellent. *Hyptis suaveolens* called “Okwekwe” by the Igede people of Benue and Cross River States of Nigeria (Igoli *et al.*, 2003). *H. suaveolens* is between 0.2 and 1.0 m tall and has remarkable odour, which has a repelling effect on insects (Raja, *et al.*, 2005)). The seeds are tiny and dark brown in colour. It is an age-old practice to protect cowpeas with the pungent smelling inflorescence of *Hyptis spicigera* Lam. (Raja, *et al.*, 2005). The use of dried twig (Raja, *et al.*, 2005), dried ground shoot and leaf powder of Poit. against stored product insect pests is also well know. This is quite different from the use of seed extract where there may be some active ingredient effect. Early work has reported that the African bush tea, *H. suaveolens*, possesses certain alkaloids, acids and phenol. *H. suaveolens* is used for some Ethnobotanical applications in rural communities and the plant is readily available close to villages, along roadsides, on farm steads etc. It has been established that, *H. Suaveolens* Poit contain some compounds that can control insects and nematodes. The exorbitant cost of conventional insecticides and the problems of insecticide resistance and environmental unfriendliness make it expedient to consider the potential of this locally available plant and its product. *Hyptis suaveolens* (L.) Poit essential oils as fumigant against storage grain insect *Tribolium castaneum* Herbst. Essential oils (EOs) from *Ageratum conyzoides* L., *Coleus aromaticus* Benth and *Hyptis suaveolens* (L.) Poit were extracted and tested against *Tribolium castaneum* Herbst, the storage grain insect. The EOs were found effective against *Tribolium castaneum* during in vitro as well as in vivo fumigant testing. The EOs of *H. suaveolens* and *A. conyzoides* showed 100 % mortality of test insect at 250 ppm while *C. aromaticus* at 350 ppm. During in vivo fumigant testing of wheat samples against *Tribolium castaneum*, the essential oils of *A. conyzoides* and *C. aromaticus* completely checked the damage of wheat grains by the insect at 1000 ppm while essential oil of *H. suaveolens* checked the grain damage completely even at 500 ppm concentration. There was no adverse effect on seed germination as well as on seedling growth of EOs treated seeds showing non-phytotoxic nature of the oils. Hence, these EOs may be recommended as botanical insecticide against insect invasion of stored food commodities, thereby enhancing their shelf life. Extract of African bush tea seed (*Hyptis suaveolens* Poit.) For the control of cowpea beetle (*Callosobruchus maculatus* Fabricius). Powdered seeds of *Hyptis suaveolens* Poit. (Labiatae) were extracted with methanol at 64-650° C in Soxhlet extraction unit. The extract was placed over a water bath at 600° C to evaporate the methanol which was used as solvent. Newly emerged adults of *Callosobruchus maculatus* F. (about 2-day old) were used in the evaluation of the toxicity of this extract. Different concentrations obtained by diluting the

extract with acetone were prepared for use. The experiment was conducted in the laboratory at $28\pm 2^{\circ}\text{C}$ and $75\pm 5\%$ relative humidity (Raja, *et al.*, 2005). At all concentrations the extract had significant effect ($P < 0.05$) on *C. maculatus* compared to the extract-free control (acetone alone). From these results of the experiments, it is concluded that *H. suaveolens* seed extract serves as toxicant against *C. maculatus* on stored cowpea. *H. suaveolens* has high toxicity and it is non-persistent. Insecticidal deterrence of wild spikenard (*Hyptis suaveolens* L. poit) on adult mortality and female oviposition of groundnut bruchid, caryedon serratus olivier on stored groundnut seeds and tamarind pods (Raja, *et al.*, 2005).

Methodology

Experimental site

The research was carried out at the entomology laboratory of Biology Department, Federal University of Technology Akure Nigeria. The temperature and relative Humidity of the research was 27 ± 2 and 75 ± 5 respectively, the site has enough ventilation all the windows were left opened to aid the biological activities of the rice weevil (*Sitophilus oryzae*) and saw-toothed beetle (*Oryzaephilus surinamensis*).

Rice cultivars

The rice cultivars used for this research were collected from the eleven local government out of the local governments in the South west Nigeria. The rice cultivar was then identified at African Rice section of International Institute of Tropic Agriculture (IITA) Ibadan. The identified rice and their locations are FARO 58a (Erinoke), FARO 58b (Igbemo), NERICA 7 (Aisegba), FARO44a (Ijero), FARO 52a(Okoko), FARO 52b(Koka), FARO 44b(Bodija), FARO44c (Akure), FARO 62 (Ofada 1a) (Obafemi Owode), FARO 62 (Ofada 1b) and FARO 63 (Ofada2) (Papalantoro). Four kilograms each of the rice cultivars was obtained and packed in portable hessian sack for effective ventilation and transported to the laboratory and physical parameters were assessed immediately and then stalked in a net cage to aid aeration.

Insect collection and insect Culture

Collection and Culture of *Sitophilus oryzae*

Parent stock of *Sitophilus oryzae* was obtained from naturally infested commodities purchased from the local market in the South West of Nigeria. The insects were maintained on uninfested rice grains. Ten adults of *S. oryzae* and *O. surinamensis* was used to produce the pure culture raised on 100 g of rice grains. The cultures were kept in the laboratory. The insects will be reared in the laboratory on the clean whole and milled rice respectively at $28\pm 2^{\circ}\text{C}$ and relative humidity of $75\pm 5\%$. The culture was maintained by replacing already sifted grains with uninfested rice grains. The First Filial adults of *S. oryzae* and *O. surinamensis* used for subsequent experiments was obtained from the existing culture in the laboratory. *Sitophilus oryzae* population was collected from the Storage research Laboratory of Biology department, Federal University of Technology Akure, Ondo State, Nigeria.

Collection and Culture of *Oryzaephilus surinamensis*

The parent stock of *Oryzaephilus surinamensis* was obtained from the parent stock at Entomology Laboratory of Zoology Department, University of Ibadan. The cultures were maintained to obtain *Oryzaephilus surinamensis* of similar age for the experiment. 200grams of the sampled rice from Erinoke (FARO 58a) were cleaned to remove the physically damaged grain and other contaminants. The cleaned grains were then placed in the refrigerator at -4°C for 1 month and for disinfestation 7days in deep freezer at $-20 \pm 2^{\circ}\text{C}$. Since *Oryzaephilus surinamensis* is a primary pest, rice was broken into smaller sizes. The grains were then transferred into plastic cups for experimental conditions for 2 weeks. The insects were then introduced into the plastic cups (25 cm height and 15 cm diameters) containing the grains. The containers were covered with muslin cloth (lid with hole of 15 cm diameter each) to allow proper aeration and to prevent the entry and exit of the insects.

Plant samples collected

Fresh leaves of the *Agerantum conyzoides* (Goat weed (Imi esu)), *Petiveria alliacea* (Guinea hen weed (Awogba / Ojusaju)) and *Hyptis suaveolens* (Pig nut (Arunfofo)) was obtained from Farms surrounding FUTA farms respectively, air dried and pulverized. The powdered sample will be passed through 25-mesh sieve to obtain fine and uniform powder. The powder of leave was stored in a tight bottle until the time needed for insect's bioassay.

Extraction of oil: To extract the oil, the required amount of pulverized plant materials will be put in a muslin cloth and transferred into a thimble and extracted through a Soxhlet extractor using methanol. Extraction will last for 4 h. Solvent will be separated from the extract. The extract was freeze dried to remove the trace of the solvent. The extract was then kept in labeled dark bottles with lid and placed in a cooled place until it was required.

Evaluation of *S. oryzae* and *O. surinamensis* on treated rice cultivars

Ten grammes of local rice collected from different local government areas was weighed separately into 250 ml plastic containers. The oil extracted from the botanicals was measured in the following percentage: 0.5 %, 1.0 %, 1.5 %, 2.0 % and 2.5 % respectively. The oil was mixed thoroughly with the rice inside plastic containers while rice without oil extracts will serve as control. Ten newly hatched adults of *S. oryzae* and *O. surinamensis* were separately introduced into those treated rice cultivars at different dosages. Mortality was assessed at 24hrs, 48hrs, 72hrs, 96h and 120hrs after treatment. The experiment was setup in a Completely Randomized Design and each treatment was in three replicates. Dead and live insects were removed after 120hrs and the number of mortalities was counted and recorded. Also, percentage adult emergence, percentage seed damage and weight loss will be calculated using the following formulae below:

$$\% \text{ Adult emergence} = \frac{\text{number of insect emergence}}{\text{Total number of egg laid}} \times \frac{100}{1}$$

$$\% \text{ weight loss} = \frac{\text{initial weight} - \text{Final weight}}{\text{Initial Weight}} \times \frac{100}{1}$$

Contact toxicity of oil extract on *S. oryzae* and *O. surinamensis*

The rice cultivars were treated with varied plant extract concentrates. Ten unsexed adult *S. oryzae* and *O. surinamensis* was then introduced to the treated rice grains. Mortalities of insects was observed after 24h. The number of dead insects were collected for control mortality using Abbott (1925) formula. The LC₅₀ and LC₉₀ values was calculated using Probit analysis (Finney 1971).

Experimental setup

Twenty grammes of local rice samples collected from different local governments was weighed separately into 250ml plastic containers. Ten newly hatched (0-24hrs old) adults of the insects were introduced on the samples in the plastic cups (25 cm height and 15 cm diameters) containing the grains of rice.

The experiment was laid out in Completely Randomized Design (CRD) with three replications. The development was observed until the emergence of a new generation of insects. Adult mortality, number of F1 progeny, weevil development time was recorded.

Statistical analysis

Analysis of variance was used to compare the differences among the botanicals and Duncan was used as Post Hoc test for significance.

Result and Discussion

1.1 Percentage Mortality of *Oryzaephilus surinamensis*

The percentage mortality of *Oryzaephilus surinamensis* on the botanical treated FARO 58a is presented in table 1. The mortality of *O. surinamensis* in the treated rice cultivar with *A. conyzoides*, *P. alliacea* and *H. suaveolens* is showed. At 0.5 concentration, 6.67% of *O. surinamensis* was recorded in all the botanicals at 24hrs. The values were no significantly different from one another ($p < 0.05$) and the control. With the same concentration, as the time of exposure increase the percentage mortality increase, At 48hrs *A. conyzoides* (13.33%), *P. alliacea* (13.33%) and *H. suaveolens* (26.67%). There is no statistically significant difference among the value at $p < 0.05$ and the control. At 72hrs *A. conyzoides* (20.00%), *P. alliacea* (23.33%) and *H. suaveolens* (30.00%). The values were not significantly different from one another. At 120hrs *A. conyzoides* (53.33%), *P. alliacea* (53.33%) and *H. suaveolens* (50.00%). There is no statistically significant difference among the values. At 1.00 concentration, At 24hrs *A. conyzoides* (3.33%), *P. alliacea* (20.00%) and *H. suaveolens* (20.00%). There is no statistically significant difference among the values. After 48hrs *A. conyzoides* cause 16.67%, *P. alliacea* (30.00%) and *Hyptis suaveolens* (36.67%). There is a statistically significant difference between the value *A. conyzoides* and *H. suaveolens* but no significant difference in *A. conyzoides* and the control. For 2.5% concentration, at 24hrs *Agerantum conyzoides* have 20.00%, *Petiveria alliacea* (10.00%) and *Hyptis suaveolens* (33.33%) mortality of *Oryzaephilus surinamensis*. There is no statistically significant difference among the value *A. conyzoides*, *P. alliacea* and the control but there is a significant difference the mortality recorded on the treatment of *H. suaveolens*, *P. alliacea* and the control. At 48hours *A. conyzoides* have 26.67.00%, *P. alliacea* (26.67%) and *H. suaveolens* (60.00%) mortality of *Oryzaephilus surinamensis*. The value of *H. suaveolens* shows a

significant difference from the control while other control is not significant different from the control. At 72hrs *A. conyzoide* have 36.67%, *P. alliacea* (43.33%) and *H. suaveolens* (73.33%) mortality of *Oryzaephilus surinamensis*. The value of *H. suaveolens* was significantly different from that of the control and other two botanicals. At 96hours, 60.00% mortality of *O. surinamensis* was recorded on *A. conyzoide*, 66.67% on *P. alliacea* while 100.00% mortality was recorded on *H. suaveolens*. There is a significant difference in the value recorded on *H. suaveolens* and other botanicals with the control. At 120hrs with the same concentration (2.5%), 80% mortality of *O. surinamensis* on *A. conyzoide*, 80% was recorded on *P. alliacea* while 100.00% mortality was recorded on *H. suaveolens*. The value from the three botanical *A. conyzoide*, *P. alliacea* and *H. suaveolens* was significantly different from the control. *H. suaveolens* showed the highest mortality of *O. surinamensis* at concentration of 2.5% and

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
<i>A. conyzoide</i>	0.5	6.67±6.67ab	13.33±6.67ab	20.00±10.00ab	33.33±6.67b	53.33±6.67bcd
<i>P. alliacea</i>		6.67±6.67ab	13.33±6.67ab	23.33±3.33abc	46.67±3.33cdef	53.33±3.33bcd
<i>H. suaveolens</i>		6.67±3.33ab	26.67±8.82abcd	30.00±5.77abcd	36.67±6.67bc	50.00±11.55bcd
<i>A. conyzoide</i>	1.0	3.33±3.33a	16.67±3.33ab	26.67±6.67abcd	33.33±3.33b	43.33±3.33b
<i>P. alliacea</i>		20.00±10.00abc	30.00±5.77bcde	46.67±6.67def	56.67±3.33cdef	63.33±3.33bcde
<i>H. suaveolens</i>		20.00±11.54abc	36.67±3.33cdef	40.00±15.27bdefg	56.67±12.01cdef	70.00±10.00cdef
<i>A. conyzoide</i>	1.5	6.67±3.33ab	20.00±0.00abc	23.33±3.33abc	33.33±3.33b	46.67±6.67bc
<i>P. alliacea</i>		26.67±3.33bcd	43.33±3.33defg	53.33±6.66efg	63.33±3.33def	73.33±3.33def
<i>H. suaveolens</i>		20.00±5.77abc	50.00±0.00fg	60.00±5.77fg	63.33±8.82def	83.33±8.82efg
<i>A. conyzoide</i>	2.0	10.00±5.77ab	16.67±3.33ab	30.00±5.77abcd	43.33±3.33bcf	70.00±5.77cdeffg
<i>P. alliacea</i>		26.67±6.67bcd	36.67±3.33cdef	46.67±8.81def	66.67±3.33ef	90.00±5.77fg

<i>H. suaveolens</i>		43.33±3.33d	46.67±6.67efg	53.33±3.33efg	76.67±12.02f	86.67±6.67efg
<i>A. conyzoides</i>	2.5	20.00±10.00abc	26.67±3.33abcd	36.67±3.33bcde	60.00±5.77def	80.00±5.77efg
<i>P. alliacea</i>		10.00±10.00ab	26.67±6.67abcd	43.33±6.67cdef	66.67±6.67ef	80.00±15.28efg
<i>H. suaveolens</i>		33.33±3.33cd	60.00±5.77g	73.33±3.33g	100.00±0.00g	100.00±0.00g
Control	0	6.67±3.33ab	10.00±0.00a	10.00±0.00a	13.33±3.33a	13.33±3.33a

120hrs, although the value increase as the time of exposure increases.

Table 1: Percentage Mortality of *Oryzaephilus surinamensis* on FARO 58a

Table 2: Percentage Mortality of *Oryzaephilus surinamensis* on FARO 58b

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
<i>A. conyzoides</i>	0.5	26.67±16.67cd e	46.67±17.64d e	50.00±15.28c de	56.67±17.64c de	43.33±17.64ab
<i>P. alliacea</i>		3.33±5.77ab	10.00±5.77ab	23.33±3.33ab c	30.00±5.77ab c	30.00±5.77ab
<i>H. suaveolens</i>		6.67±3.33ab	26.67±8.82ab cd	30.00±5.77ab cd	36.67±8.82ab cd	50.00±11.55ab cd
<i>A. conyzoides</i>	1.0	16.67±8.82abc	36.67±3.33cd e	60.00±15.27d e	40.00±15.28b cd	40.00±15.28ab
<i>P. alliacea</i>		3.33±3.33ab	10.00±5.77aa	13.33±8.82ab	23.33±3.33ab	30.00±5.77cdef
<i>H. suaveolens</i>		20.00±11.55ab cd	36.67±12.02c d	40.00±15.28b cd	56.67±12.02c de	70.00±10.00cd ef
<i>A. conyzoides</i>	1.5	23.33±6.67abc	40.00±10.00c	53.33±12.02c	66.67±6.67ab	86.67±3.33f

<i>conyzoide</i>		d	de	de	cd	
<i>P. alliacea</i>		10.00±5.77abc	16.67±3.33ab	23.33±6.67ab	36.67±12.01d	73.33±21.86cd
<i>H.</i>		20.00±5.77abc	50.00±0.00de	60.00±5.77de	63.33±12.02d	83.33±8.82ef
<i>suaveolens</i>		d			e	
<i>A.</i>	2.0	16.67±6.67abc	30.00±5.77bc	43.33±8.82cd	50.00±5.77bc	73.33±8.82cde
<i>conyzoide</i>			d		de	f
<i>P. alliacea</i>		6.67±6.67ab	16.67±3.33a	26.67±8.82ab	36.67±8.82ab	76.67±12.01de
<i>H.</i>		43.33±3.33d	46.67±6.67de	53.33±3.33cd	76.67±12.02e	86.67±6.67f
<i>suaveolens</i>				e	f	
<i>A.</i>	2.5	43.33±12.01	46.67±8.2de	53.33±6.67cd	66.67±6.67de	76.67±3.33def
<i>conyzoide</i>				e		
<i>P. alliacea</i>		23.33±3.33abc	30.00±0.00bc	36.67±3.33bc	50.00±0.00bc	86.66±8.2f
<i>H.</i>		d	d	d	de	
<i>suaveolens</i>		33.33±3.3334	60.00±5.77e	73.33±3.33de	100.00±0.00f	100.00±0.00f
Control	0	0.00±0.00a	3.33±3.33a	3.33±3.33a	6.67±6.67a	13.33±3.33a

Table 3: Percentage Mortality of *Oryzaephilus surinamensis* on FARO 58a (Probit)

Plant Extract	Exposure Period	Intercept± S.E.	Slope± S.D.	R^2	LC ₅₀ (LCL - UCL)	LC ₉₀ (LCL -UCL)	P value
<i>A. conyzoide</i>	24 hours	3.47±0.21	1.20±0.83	0.82	17.36 (6.69 – 45.09)	192 (73.99 – 499.07)	0.43
	48 hours	4.03±0.35	0.59±1.69	0.80	14.78 (8.68 - 41.12)	58 (21.11 – 115.46)	0.84
	72 hours	4.31±0.29	0.66±1.51	0.90	10.94 (2.98 – 40.19)	39.06 (28.7- 93.55)	0.94
	92 hours	4.67±0.23	0.79±1.26	0.54	2.62 (0.94 - 7.28)	11.10 (9.91 – 30.84)	0.36

	120 hours	5.08±0.13	1.38±0.73	0.79	0.87 (0.48 – 1.59)	7.66 (4.21 – 13.92)	0.62
<i>P. alliacea</i>	24 hours	3.87±0.15	1.40±0.71	0.94	6.45 (3.25 – 12.78)	53.75(26.88 – 105.6)	0.79
	48 hours	4.33±0.13	1.47±0.68	0.97	2.86 (1.59 – 5.13)	21.44 (11.98 – 38.3)	0.93
	72 hours	4.68±0.17	1.07±0.94	0.89	1.99 (0.93 – 4.27)	19.36 (10.93 – 38.0)	0.81
	92 hours	4.85±0.16	1.14±0.88	0.91	1.35 (0.66 – 2.75)	18.21 (8.92 – 37.15)	0.91
	120 hours	5.33±0.10	1.91±0.52	0.89	0.67 (0.43 – 1.06)	3.19 (1.89 – 4.73)	0.76
<i>H. suaveolens</i>	24 hours	4.04±0.11	1.78±0.56	0.94	3.45 (2.07 – 5.75)	18.16(10.91 – 30.23)	0.65
	48 hours	4.70±0.84	1.19±0.84	0.97	1.77 (0.89 – 3.49)	20.86(10.55 – 41.24)	0.98
	72 hours	4.86±0.12	1.56±0.64	0.94	1.24 (0.73 – 2.09)	8.27 (4.88 – 13.99)	0.88
	92 hours	5.15±0.11	1.67±0.59	0.97	0.81 (0.49 – 1.35)	4.76 (2.88 – 7.88)	0.54
	120 hours	5.57±0.11	1.91±0.52	0.99	0.51 (0.31 – 0.82)	2.37 (1.46 – 3.85)	0.95

Note: R² = Statistical measure of mortality proportion in regression model

S. E. = Standard error

S. D. = Standard deviation

LC₅₀ = Lethal concentration at which 50% population response

LC₉₀ = Lethal concentration at which 90% population response

LCL = Lower confidence limit

UCL = Upper confidence limit

P-value = Chi -square (X^2) Significant.

Table 4: Percentage Mortality of *Sitophilus oryzae* on FARO 58a (Probit)

Plant Extract	Exposure Period	Intercept± S.E.	Slope± S.D.	R^2	LC ₅₀ (LCL - UCL)	LC ₉₀ (LCL -UCL)	P value
	24 hours	3.72±0.32	0.73±1.37	0.97	15.93 (10.4 – 23.43)	93.15(55.58-123.32)	0.99

<i>A. conyzoides</i>	48 hours	3.93±0.21	1.01±0.99	0.79	11.86 (4.61 – 20.51)	39.33(13.04 – 61.5)	- 0.45
	72 hours	4.35±0.34	0.56±1.79	0.96	8.85 (3.20 – 18.89)	27.24 (14.21- 45.78)	0.99
	92 hours	4.70±0.22	0.81±1.24	0.52	2.34 (0.86 – 6.39)	13.15 (3.17 -25.38)	0.36
	120 hours	4.88±0.24	0.74±1.35	0.58	1.45 (0.49 – 4.28)	8.52 (2.53 – 14.24)	0.67
<i>P. alliacea</i>	24 hours	3.73±0.15	1.54±0.65	0.94	6.79 (3.54 – 13.06)	47.29 (24.62 – 90.8)	0.74
	48 hours	3.98±0.28	0.73±1.33	0.95	4.25 (2.07 – 9.86)	36.04 (20.16 – 78.91)	0.97
	72 hours	4.35±0.17	1.11±0.90	0.92	3.87 (1.79 – 8.33)	25.07 (15.56 – 39.18)	0.85
	92 hours	4.74±0.23	0.79±1.26	0.55	2.14 (0.77 – 5.93)	19.21 (12.55 – 31.02)	0.48
<i>H. suaveolens</i>	120 hours	5.17±0.15	1.19±0.84	0.92	0.73 (0.36 – 1.45)	8.69 (4.35 – 17.36)	0.01
	24 hours	4.30±0.33	0.58±1.73	0.96	16.08 (3.61 – 71.74)	68.62 (60.21- 88.50)	0.99
	48 hours	4.59±0.17	1.11±0.91	0.98	2.35 (1.12 – 4.94)	33.90 (16.12 – 71.32)	0.98
	72 hours	4.99±0.31	0.57±1.76	0.91	1.06 (0.26 – 4.37)	19.30 (14.69 – 45.70)	0.99
<i>H. suaveolens</i>	92 hours	5.39±0.71	1.41±0.71	0.99	0.53 (0.29 – 0.97)	4.27 (2.55 – 8.67)	0.99
	120 hours	5.80±0.12	1.82±0.55	0.97	0.36 (0.21 – 0.62)	1.85 (1.08 – 3.18)	0.99

Note: R² = Statistical measure of mortality proportion in regression model

S. E. = Standard error

S. D. = Standard deviation

LC₅₀ = Lethal concentration at which 50% population response

LC₉₀ = Lethal concentration at which 90% population response

LCL = Lower confidence limit

UCL = Upper confidence limit

P-value = Chi -square (X^2) Significant.

1.2 Lethal Dosage of three botanicals Required to cause 50% and 90%

Mortality of *Oryzaephilus surinamensis*

The lethal dosage (LD) of three botanicals extract against adult *Oryzaephilus surinamensis* are presented in table 3. The required concentration of *Ageratum conyzoides* needed to achieve 50% (LD₅₀) mortality of *Oryzaephilus surinamensis* after 24hours, 48hours, 72hours, 92 hours and 120 hours exposure were 17.36,14.78, 10.94,2.62 and 0.87 respectively. The concentration required to achieve 90% (LD₉₀) mortality of *Oryzaephilus surinamensis* using *Ageratum conyzoides* are 192, 58, 39.06, 11.10 and 7.66 for 24,48, 72, 96 and 120 hours of exposure respectively. The regression linear (R^2) calculated for the 24 hours, 48 hours, 72 hour, 96 hours and 120hours were 0.82, 0.80, 0.90, 0.54 and 0.79 respectively.

The concentration of *Petiveria alliacea* extract needed to cause 50% (LD₅₀) mortality *Oryzaephilus surinamensis* for 120 hours of exposure were 6.45, 2.86, 1.99, 1.35 and 0.67 respectively. The lethal concentration of *P.alliacea* leaf needed to achieve 90% (LD₉₀) mortality of *Oryzaephilus surinamensis* after 24 hrs, 48 hrs, 72 hrs, 96 hrs and 120 hrs of exposure were 53.75, 21.44, 19.36, 18.21 and 3.19 respectively. The regression linear (R^2) calculated for the 24 hours, 48 hours, 72 hour, 96 hours and 120 hours were 0.94, 0.97, 0.89, 0.91 and 0.98 respectively.

The concentration of *Hyptis suaveolens* leave extract that required to cause 50% (LD₅₀) mortality of *Oryzaephilus surinamensis* for 120 hrs exposure were 3.45, 1.77, 1.24, 0.81 and 0.51 respectively. The lethal dose of *Hyptis suaveolens* leave extract that required to cause 90% (LD₉₀) mortality of *Oryzaephilus surinamensis* after 120hours were 18.6, 20.86, 8.27, 4.76 and 2.37 respectively. The regression linear (R^2) calculated for the 24hours, 48hours, 72hour, 96hours and 120hours were 0.94, 0.97, 0.94, 0.97 and 0.99 respectively.

1.3 Lethal Dosage of three botanicals Required to cause 50% and 90% Mortality of

Sitophilus oryzae

The lethal dosage (LD) of three botanicals extract against adult *Sitophilus oryzae* are presented in table 4. The required concentration of *Ageratum conyzoides* needed to achieve 50% (LD₅₀) mortality of *Sitophilus oryzae* after 24hours, 48hours, 72hours, 92 hours and 120 hours exposure were 15.93, 11.86, 8.85, 2.34 and 1.45 respectively. The concentration required to achieve 90% (LD₉₀) mortality of *Sitophilus oryzae* using *Ageratum conyzoides* are 93.15, 39.33, 27.24, 13.15 and 8.52 for 24,48, 72, 96 and 120 hours of exposure respectively. The regression linear (R^2) calculated for the 24 hours, 48 hours, 72 hour, 96 hours and 120 hours were 0.97, 0.79, 0.96, 0.52 and 0.58 respectively.

The concentration of *Petiveria alliacea* extract needed to cause 50% (LD₅₀) mortality *Sitophilus oryzae* for 120 hours of exposure were 6.79, 4.25, 3.87, 2.14 and 0.73 respectively. The lethal concentration of *P. alliacea* leaf needed to achieve 90% (LD₉₀) mortality of *Oryzaephilus surinamensis* after 24hrs, 48hrs, 72hrs, 96hrs and 120hrs of exposure were 47.29, 36.04, 25.07, 19.21 and 8.69 respectively. The regression linear (R²) calculated for the 24hours, 48hours, 72 hour, 96 hours and 120 hours were 0.94, 0.95, 0.92, 0.55 and 0.92 respectively.

The concentration of *Hyptis suaveolens* leave extract that required to cause 50% (LD₅₀) mortality of *Sitophilus oryzae* for 120hrs exposure were 16.08, 2.35, 1.06, 0.53 and 0.36 respectively. The lethal dose of *Hyptis suaveolens* leave extract that required to cause 90% (LD₉₀) mortality of *Sitophilus oryzae* after 120 hours were 68.62, 33.90, 19.30, 4.27 and 1.85 respectively. The regression linear (R²) calculated for the 24hours, 48hours, 72hour, 96hours and 120hours were 0.96, 0.98, 0.91, 0.99 and 0.97 respectively.

Table 5: *Oryzaephilus surinamensis* on NERICA 7

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
<i>A. conyzoide</i>	0.5	13.33±6.67a	16.66±8.82abc	33.33±5.77abc	43.33±6.67bc	46.67±3.33ab
<i>P. alliacea</i>		3.33±3.33a	10.00±5.77ab	16.66±3.33a	33.33±3.33ab	43.33±3.33ab
<i>H. suaveolens</i>		10.00±5.77a	40.00±5.77cde	60.00±15.28b	73.33±16.67d	90.00±10.00de
<i>A. conyzoide</i>	1.0	13.33±6.67a	23.33±3.3abcd	30.00±0.00ab	36.67±3.33ab	43.33±3.33ab
<i>P. alliacea</i>		23.33±3.33ab	23.33±3.33abcd	33.3±3.33abc	40.00±5.77bc	56.67±3.3b
<i>H. suaveolens</i>		20.00±11.55ab	33.33±8.82bcde	70.00±5.77d	86.67±3.33d	93.33±6.67e
<i>A. conyzoide</i>	1.5	13.33±8.82a	20.00±5.77abcd	26.67±6.67ab	36.67±6.67ab	46.67±3.33ab
<i>P. alliacea</i>		13.33±8.28a	16.67±8.82abc	26.67±6.67ab	40.00±5.77bc	83.33±8.82cde
<i>H. suaveolens</i>		40.00±5.77b	40.00±5.78cde	63.33±12.02d	70.00±11.55d	83.33±12.02cde
<i>A. conyzoide</i>	2.0	16.67±8.82ab	23.33±6.67abcd	30.00±5.77ab	33.33±3.33ab	50.00±10.00b
<i>P. alliacea</i>		16.67±12.02ab	20.00±10.00abcd	30.00±10.00ab	40.00±5.77bc	60.00±11.55bc
<i>H. suaveolens</i>		26.67±12.02ab	53.33±12.01e	63.33±12.02d	83.33±3.33d	96.66±3.33e

<i>suaveolens</i>						
A.	2.5	16.67±3.33ab	26.67±3.33abcd	33.33±8.82cd	46.67±8.82bcd	66.67±16.6bcd
<i>conyzoide</i>						
P. alliacea		20.00±10.00ab	33.33±3.33bcde	56.67±8.82bcd	63.33±3.33cde	93.33±6.67e
H.		16.66±8.82ab	43.33±8.82de	56.67±8.82cd	66.67±6.67de	96.67±3.33e
<i>suaveolens</i>						
Control	0	3.33±3.33a	3.33±3.33a	6.67±6.67a	13.33±3.33a	23.33±6.67a

Note: Means followed by the same letter in column are not significant different (p>0.05)

Table 6: The percentage mortality of *Sitophilus oryzae* on the botanical treated FARO 58b

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
A.		6.67±6.67ab	6.67±6.67a	33.33±3.33bcde	36.67±6.67b	40.00±5.77b
<i>conyzoide</i>						
P. alliacea	0.5	3.33±3.33a	10.00±5.77a	16.67±3.33ab	33.33±3.33ab	43.33± 3.33b
H.		26.67±8.82ab	33.33±3.33bcd	50.00±5.77ef	50.00±5.77bc	60.00±5.77bcd
<i>suaveolens</i>						
A.	1.0	13.33±6.67ab	23.33±3.33abc	30.00±0.00bcd	36.67±3.33b	43.33±3.33b
<i>conyzoide</i>						
P. alliacea		23.33±3.33ab	23.33±5.77abc	33.33±3.33bcde	40.00±5.77b	56.67±3.33bcd
H.		23.33±12.02ab	23.33±3.33abc	50.00±0.00bcde	63.33±3.33cd	76.67±8.82def
<i>suaveolens</i>						
A.	1.5	13.33±8.82aab	20.00±5.77ab	26.67±6.67abc	36.67±6.67b	46.67±8.81bc
<i>conyzoide</i>						
P. alliacea		13.33±8.82ab	16.67±8.82ab	26.67±6.67abc	40.00±10.00b	73.33±3.33bcd
H.		23.33±12.02ab	40.00±0.00cd	43.33±3.33cdef	73.33±14.53d	90.00±10.00f
<i>suaveolens</i>						
A.	2.0	16.67±8.82ab	23.33±6.67ab	30.00±5.77bcd	33.33±3.33ab	46.67±8.82bc
<i>conyzoide</i>						

<i>P. alliaceae</i>		16.67±12.02ab	20.00±10.00ab	30.00±10.00bcd	40.00±10.00b	60.00±11.55bcd
<i>H. suaveolens</i>		30.00±5.77b	50.00±5.77d	60.00±5.77f	80.00±5.77d	93.33±3.33f
<i>A. conyzoides</i>						
<i>A. conyzoides</i>	2.5	10.00±5.77ab	20.00±5.77ab	26.67±3.33abc	40.00±5.77b	66.67±8.82f
<i>P. alliaceae</i>		20.00±10.00ab	33.33±3.33bcd	46.67±3.33def	63.33±3.33cd	83.33±3.33ef
<i>H. suaveolens</i>		30.00±5.77b	50.00±5.77d	56.67±12.02f	83.33±12.02d	90.00±5.77f
Control	0	6.67±3.33ab	10.00±0.00a	10.00±0.00a	13.33±3.33a	13.33±3.33a

Note: Means followed by the same letter in column are not significant different ($p > 0.05$)

1.3 The percentage mortality of *Oryzaephilus surinamensis* on the botanical treated NERICA 7

The percentage mortality of *Oryzaephilus surinamensis* on the botanical treated NERICA 7 is presented in table 5. The mortality of *O. surinamensis* in the treated rice cultivar with *A. conyzoides*, *P. alliaceae* and *H. suaveolens* is showed. At 0.5 concentration, 13.33% of *O. surinamensis* was recorded in *A. conyzoides*, 3.33% in *P. alliaceae* and 10.00% *H. suaveolens* after a24hours of exposure. The values were no significantly different from one another ($p < 0.05$) and the control. With the same concentration, as the time of exposure increase the percentage mortality increase at 48 hrs *A. conyzoides* (16.66%), *P. alliaceae* (10.00%) and *H. suaveolens* (40.00%). There is a statistically significant difference between the experimental values at $p < 0.05$ and the control. At 72 hrs *A. conyzoides* (33.33%), *P. alliaceae* (16.66%) and *H. suaveolens* (60.00%). The values from *P. alliaceae* were not significantly different from the control but different from other botanicals. At 120hrs *A. conyzoides* (46.67%), *P. alliaceae* (43.33%) and *H. suaveolens* (90.00%). There is no statistically significant difference among the values recorded from *A. conyzoides*, *P. alliaceae* and the control but they different statistically from the value recorded in *H. suaveolens* at 120hours of exposure.

At 1.00 concentration 24hrs *A. conyzoides* (13.33%), *P. alliaceae* (23.00%) and *H. suaveolens* (20.00%). There is no statistically significant difference among the values. After 48hrs *A. conyzoides* cause 23.33%, *P. alliaceae* (23.00%) and *Hyptis suaveolens* (33.33%). There is a statistically significant difference between the value *A. conyzoides* and *H. suaveolens* but no significant difference in *A. conyzoides* and the control. For 2.5% concentration, at 24hrs *Agerantum conyzoides* have 16.67%, *Petiveria alliaceae* (20.00%) and *Hyptis suaveolens* (16.66%) mortality of *Oryzaephilus surinamensis*. There is no statistically significant difference among the value *A. conyzoides*, *P. alliaceae*, *Hyptis suaveolens* and the control. At 48 hours *A. conyzoides* have 26.67.00%, *P. alliaceae* (33.33%) and *H. suaveolens* (43.33%) mortality of *Oryzaephilus surinamensis*. Comparing the result with control, no statistical difference between the botanicals but a significant difference was recorded between the value recorded in *A. conyzoides* and the control. At 72hrs *A. conyzoides* have 33.33%, *P. alliaceae* (56.67%) and *H. suaveolens* (56.67%) mortality of *Oryzaephilus surinamensis*. At 96 hours, 46.67% mortality of *O. surinamensis* was

recorded on *A. conyzoides*, 63.33% on *P. alliacea* while 66.67% mortality was recorded on *H. suaveolens*. There is no significant difference in the values recorded in the botanicals but different they are differing from the value recorded in the control. At 120hrs with the same concentration (2.5%), 66.67% mortality of *O. surinamensis* on *A. conyzoides*, 93.33% was recorded on *P. alliacea* while 96.67.00% mortality was recorded on *H. suaveolens*. No statistical difference recorded in *P. alliacea* and *H. suaveolens* but they are both differ statistically from the value gotten on *A. conyzoides*. They are all differ from the control. *H. suaveolens* showed the highest mortality of *O. surinamensis* at concentration of 2.5% and 120 hrs (96.67), although the value increase as the time of exposure increases.

1.4 The percentage mortality of *Sitophilus oryzae* on the botanical treated FARO 58b

The percentage mortality of *Sitophilus oryzae* on the botanical treated FARO 58 is presented in table 6. The mortality of *Sitophilus oryzae* in the treated rice cultivar with *A. conyzoides*, *P. alliacea* and *H. suaveolens* is showed. At 0.5 concentration, 6.67% of *S. oryzae* was recorded in *A. conyzoides*, 3.33% in *P. alliacea* and 26.67% *H. suaveolens* after 24hours of exposure. The values were not significantly different from one another ($p < 0.05$) and the control. With the same concentration, as the time of exposure increase the percentage mortality increase, At 48hrs *A. conyzoides* (6.67%), *P. alliacea* (10.00%) and *H. suaveolens* (33.33%). There is a statistically significant difference between the experimental values at $p < 0.05$ and the control. At 72hrs *A. conyzoides* (33.33%), *P. alliacea* (16.66%) and *H. suaveolens* (50.00%). The values from the botanicals were significantly differ from the control except that of *P. alliacea*. At 120 hrs *A. conyzoides* (40.00%), *P. alliacea* (43.33%) and *H. suaveolens* (60.00%). There is no statistically significant difference among the values recorded from *A. conyzoides*, *P. alliacea* and *H. suaveolens* but are all differ from the control after 120hours of exposure.

At 1.00 concentration, At 24hrs *A. conyzoides* (13.33%), *P. alliacea* (23.00%) and *H. suaveolens* (23.33%). There is no statistically significant difference among the values recorded in the botanicals and the control. After 48hrs *A. conyzoides* cause 23.33%, *P. alliacea* (23.33%) and *Hyptis suaveolens* (23.33%). There is no statistically significant difference between the values from the botanical and the control. For 2.5% concentration, at 24hrs *Agerantum conyzoides* have 10.00%, *Petiveria alliacea* (20.00%) and *Hyptis suaveolens* (30.00%) mortality of *Sitophilus oryzae*. There is no statistically significant difference among the value *A. conyzoides*, *P. alliacea*, *Hyptis suaveolens* and the control. At 48hours *A. conyzoides* have 20.00%, *P. alliacea* (33.33%) and *H. suaveolens* (50.00%) mortality of *Sitophilus oryzae*. Comparing the result with control, no statistical difference between the *A. conyzoides* and the control but a significant difference was recorded between the value recorded in *A. conyzoides*, *P. alliacea* and the control but they are statistically differ from *H. suaveolens* result. At 72hrs *A. conyzoides* have 26.67%, *P. alliacea* (46.67%) and *H. suaveolens* (56.67%) mortality of *Sitophilus oryzae*. At 96hours, 40.00% mortality of *O. surinamensis* was recorded on *A. conyzoides*, 63.33% on *P. alliacea* while 83.33% mortality was recorded on *H. suaveolens*. There is no significant difference in the values recorded in the botanicals and that recorded in the control. At 120 hrs. with the same concentration (2.5%), 66.67% mortality of *O. surinamensis* on *A. conyzoides*, 83.33% was recorded on *P. alliacea* while 90.00% mortality was recorded on *H. suaveolens*. No statistical difference recorded in the botanicals but they are statistically from the value gotten on the control. *H. suaveolens* has the highest mortality of *S. oryzae* at concentration of 2.5% and 120hrs (90.67), although the value increase as the time of exposure increases.

Table 7: The percentage mortality of *Sitophilus oryzae* on the botanical treated FARO 58b

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
<i>A. conyzoide</i>	0.5	6.67±6.67ab	11.57±6.67ab	23.33±3.33abc	46.67±3.33bcd	53.33±3.33bc
<i>P. alliacea</i>		6.67±6.67ab	13.33±6.67ab	20.00±10.00ab	33.33±6.67a	53.33±6.67bc
<i>H. suaveolens</i>		26.67±8.83ab	33.33±3.33defg	50.00±5.77efg	50.00±5.77bcd	60.00±5.67bcd
<i>A. conyzoide</i>	1.0	20.00±10.00ab	30.00±5.77cdefg	46.67±6.67defg	56.67±3.33b	63.33±3.33bcd
<i>P. alliacea</i>		3.33±3.33a	16.67±3.33abc	26.67±6.67abcd	33.33±3.33b	43.33±6.67b
<i>H. suaveolens</i>		10.00±5.77ab	23.33±3.33abcde	50.00±0.00efg	63.33±3.33cdefg	76.67±8.82def
<i>A. conyzoide</i>	1.5	26.67±3.33ab	43.33±3.33gh	53.33±6.67fg	63.33±3.33cdefg	73.33±3.33cdef
<i>P. alliacea</i>		6.67±3.33b	20.00±0.00abcd	23.33±3.33abc	33.33±3.33b	46.67±6.67b
<i>H. suaveolens</i>		23.33±12.03ab	40.00±0.00fgh	43.33±3.33cdefg	73.33±14.53efg	90.00±10.00ef
<i>A. conyzoide</i>	2.0	26.67±6.67ab	36.67±3.33abc	46.67±8.82defg	66.67±6.67defg	80.00±5.77def
<i>P. alliacea</i>		10.00±5.77ab	16.67±3.33abc	30.00±5.67abcde	43.33±3.33bc	70.00±5.77cde
<i>H. suaveolens</i>		30.00±5.77b	50.00±5.77h	60.00±5.77g	80.00±5.77fg	90.00±5.77ef
<i>A. conyzoide</i>	2.5	10.00±10.00b	26.67±6.67bcdef	43.33±6.67cdefg	66.67±6.67defg	73.33±12.03cdef
<i>P. alliacea</i>		20.00±10.00	26.67±3.33defg	36.67±3.33bcdef	60.00±5.77cedf	80.00±5.77def
<i>H. suaveolens</i>		30.00±5.77b	50.00±5.77h	56.67±12.02fg	83.33±3.33g	93.33±3.33f
Control	0	3.33±3.33b	6.67±3.33a	10.00±0.00a	10.00±0.00a	13.33±3.33a

Note: Means followed by the same letter in column are not significant different ($p>0.05$)

The percentage mortality of *Sitophilus oryzae* on the botanical treated is presented in table 30. The mortality of *Sitophilus oryzae* in the treated rice cultivar with *A. conyzoides*, *P. alliacea* and

H. suaveolens is showed. At 0.5 concentration, 6.67% of *S. oryzae* was recorded in *A. conyzoides*, 6.67% in *P. alliacea* and 26.67% *H. suaveolens* after 24hours of exposure. The values were not significantly different from one another ($p < 0.05$) and the control. With the same concentration, as the time of exposure increase the percentage mortality increase, At 48hrs *A. conyzoide* (11.57%), *P. alliacea* (13.33%) and *H. suaveolens* (33.33%). There is a statistically significant difference between the experimental values at $p < 0.05$ and the control. At 72hrs *A. conyzoide* (33.33%), *P. alliacea* (16.66%) and *H. suaveolens* (50.00%). The values from the botanicals were significantly differ from the control except that of *P. alliacea*. At 120hrs *A. conyzoide* (40.00%), *P. alliacea* (43.33%) and *H. suaveolens* (60.00%). There is no statistically significant difference among the values recorded from *A. conyzoides*, *P. alliacea* and *H. suaveolens* but are all differ from the control after 120hours of exposure.

At 1.00 concentration, At 24hrs *A. conyzoide* (13.33%), *P. alliacea* (23.00%) and *H. suaveolens* (23.33%). There is no statistically significant difference among the values recorded in the botanicals and the control. After 48hrs *A. conyzoide* cause 23.33%, *P. alliacea* (23.33%) and *Hyptis suaveolens* (23.33%). There is no statistically significant difference between the values from the botanical and the control. For 2.5% concentration, at 24hrs *Agerantum conyzoide* have 10.00%, *Petiveria alliacea* (20.00%) and *Hyptis suaveolens* (30.00%) mortality of *Sitophilus oryzae*. There is no statistically significant difference among the value *A. conyzoide*, *P. alliacea*, *Hyptis suaveolens* and the control. At 48hours *A. conyzoide* have 20.00%, *P. alliacea* (33.33%) and *H. suaveolens* (50.00%) mortality of *Sitophilus oryzae*. Comparing the result with control, no statistical difference between the *A. conyzoide*, and the control but a significant difference was recorded between the value recorded in *A. conyzoide*, *P. alliacea* and the control but they are statistically differ from *H. suaveolens* result. At 72hrs *A. conyzoide* have 26.67%, *P. alliacea* (46.67%) and *H. suaveolens* (56.67%) mortality of *Sitophilus oryzae*. At 96hours, 40.00% mortality of *O. surinamensis* was recorded on *A. conyzoide*, 63.33% on *P. alliacea* while 83.33% mortality was recorded on *H. suaveolens*. There is no significant difference in the values recorded in the botanicals and that recorded in the control. At 120hrs with the same concentration (2.5%), 66.67% mortality of *O. surinamensis* on *A. conyzoide*, 83.33% was recorded on *P. alliacea* while 90.00% mortality was recorded on *H. suaveolens*. No statistical difference recorded in the botanicals but they are differ statistically from the value gotten on the control. *H. suaveolens* has the highest mortality of *S. oryzae* at concentration of 2.5% and 120hrs (90.67), although the value increase as the time of exposure increases.

Table 8: The percentage mortality of *Sitophilus oryzae* on the botanical treated NERICA 7

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
<i>A. conyzoide</i>	0.5	6.66±6.66ab	13.33±6.66ab	23.33±3.33abc	46.66±3.33bcd	53.33±3.33bc
<i>P. alliacea</i>		6.67±6.66ab	13.33±6.67abc	20.00±10.00ab	33.33±6.66b	53.33±6.67bc
<i>H. suaveolens</i>		26.66±8.82ab	33.33±3.33defg	50.00 ±5.77efg	50.00±5.77bcd	60.00±5.77ef
<i>A. conyzoide</i>	1.0	20.00±10a	30.00±5.77cdefg	46.67±6.67defg	56.67±3.33cde	63.33±3.33bcd
<i>P. alliacea</i>		3.33±3.33a	16.67±3.33abc	26.66±6.67abcd	33.33±3.33b	43.33±3.33b
<i>H. suaveolens</i>		10.00±5.77ab	23.33±3.33abcde	50.00±5.77efg	63.33±3.33cdefg	76.67±8.8def
<i>A. conyzoide</i>	1.5	26.67±3.33ab	43.3±3.33gh	53.33±6.67fg	63.33±3.33cdefg	73.33±3.33cdef
<i>P. alliacea</i>		6.66±3.33ab	20.00±0.00abcd	23.33±3.33abc	33.33±3.33b	46.67±6.66b
<i>H. suaveolens</i>		23.33±12.01ab	40.00±0.00fgh	43.33±3.33cdefg	73.33±14.5efg	90.00±10.0ef
<i>A. conyzoide</i>	2.0	26.67±6.6ab	36.67±3.33efgh	46.67±8.82defg	66.67±3.33defg	80.00±5.77def
<i>P. alliacea</i>		10.00±5.77ab	16.67±3.33abc	30.00±5.77abcde	43.33±3.33bc	70.00±5.77cde
<i>H. suaveolens</i>		30.00±5.77b	50.00±5.77h	60.00±5.77g	80.00±5.77g	93.33±3.33f
<i>A. conyzoide</i>	2.5	10.00±10.0ab	26.66±3.33g	43.33±6.67cdefg	66.67±6.66defg	73.33±12.0cdef
<i>P. alliacea</i>		20.00±10.0ab	26.67±3.33bcdef	36.66±3.33bcdfg	60.00±5.77cdef	80.00±5.77def
<i>H. suaveolens</i>		30.00±5.77b	50.00±5.77h	56.67±12.01fg	83.33±12.01g	90.00±3.33ef
Control	0	6.67±3.33ab	10.00±0.00a	10.00±0.00a	13.33±3.33a	13.33±3.33a

Note: Means followed by the same letter in column are not significant different ($p>0.05$)

Discussion

Plant materials extract has been reported to be potent in preservation of stored products against insect of stored product. *Ageratum conyzoides*, *Petiveria alliacea* and *Hyptis suaveolens* extract used for this experiment showed potential protective properties against *Sitophilus oryzae* and *Oryzaephilus surinamensis* although the extract is of different potency. The potency of the botanicals *Hyptis suaveolens* showed the highest potency against *Sitophilus oryzae* and *Oryzaephilus surinamensis* on the sampled rice ($p \leq 0.05$).

Abbott W. (1925). A method for computing the effectiveness of an insecticide. - *Journal of economic entomology*, 18: 265-267.

FAO. 1991. FAOSTAT agriculture data. Food and Agriculture Organization of the United Nations. FAO. 2004. Species description *Oryza sativa* L. <http://www.fao.org/ag/AGP/AGPC/doc/GBASE/data/pf000274.htm>

Ogungbite O. C and Oyeniya E. A. (2014). *Newbouldia leavis* (Seem) as an entomocide against *Sitophilus oryzae* and *Sitophilus zeamais* infestating maize grain. *Jordan Journal of Biological Sciences*7(1):49-55.

Park, I. K., Lee, S. G., Choi, D. H., Park, J. D. and Ahn, Y. J. (2003). Insecticidal activity of constituents identified the essential oil from leaves of *Chamaecyparis obtuse* against *Callosobruchus chinensis* (L.) and *Sitophilus oryzae* (L.). *Journal of Stored Products Research*, 39: 375-384

Raja, N., Jeyasankar, A., Venkatesan, S. J., & Ignacimuthu, S. (2005). Efficacy of *Hyptissuaveolens* against lepidopteran pests. *Current Science*, 88(2), 220-222 WARD A 1997. WARD A Annual Report 1996. Mbé, Côte d'Ivoire.

Singh, P., Prakash, B., and Dubey, N. K. (2014). Insecticidal activity of *Ageratum conyzoides* L., *Coleus aromaticus* Benth. And *Hyptis suaveolens* (L.) Poit essential oils as fumigant against storage grain insect *Tribolium castaneum* Herbst. *Journal of food science and technology*, 51(9), 2210-2215.

Ashamo, M. O., Odeyemi, O.O. and Ogungbite, O.C (2013). Protection of cowpea, *Vigna unguiculata* L. (Walp) with *Newbouldia laevis* (seem) extracts against infestation by *Callosobruchus maculatus*. (Fabricus), *Archives of Phytopathology and plant protection* 46(11): 1295-1306

Ashamo M. O. (2006). Relative susceptibility of some local and elite rice varieties to the rice weevil, *Sitophilus oryzae* L. (Coleoptera: curculionidae). *Journal of food, Agriculture and environment* 4(1):249-252.

Ashamo M.O. and Ogungbite O.C. (2014) Extracts of medicinal plants as entomocide against *Sitotroga cerealella* (Olivier) infestation of paddy rice. *Medicinal plant Research* 4(18):incomplete

- Ashamo, M. O., & Odeyemi, O. O. (2001). Protection of maize against *Sitophilus zeamais* Motsch. using seed extracts from some indigenous plants. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz*, 108(3), 320-327.
- Akunne, C.E.; Ononye, B.U.; and Mogbo, T.C. (2013). Evaluation of the Efficacy of Mixed Leaf Powders of *Vernonia amygdalina* (L.) and *Azadirachta indica* (A. Juss) Against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Advances in Bioscience and Bioengineering*, 1(2):86-95.

Genetic Variations of *CYP2C9* in Thai Patients Taking Medical Cannabis

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Abstract

Medical cannabis can be used for treatment, including pain, multiple sclerosis, Parkinson's disease, and cancer. However, medical cannabis leads to adverse effects (AEs) which is delta-9-tetrahydrocannabinol (THC). In previous studies, the major of THC metabolism enzymes are *CYP2C9*. Especially, the variation of *CYP2C9* gene consist of *CYP2C9*2* on exon 3 and *CYP2C9*3* on exon 7 to decrease enzyme activity. Notwithstanding, there is no data describing whether the variant of *CYP2C9* genes are a pharmacogenetics marker for prediction of THC-induced AEs in Thai patients. We want to investigate the association between *CYP2C9* gene and THC-induced AEs in Thai patients. We enrolled 39 Thai patients with medical cannabis treatment who were classified by clinical data. The *CYP2C9*2* and **3* genotyping were conducted using the TaqMan real time PCR assay. All Thai patients who received the medical cannabis consist of twenty-four (61.54%) patients were female and fifteen (38.46%) were male, with age range 27- 87 years. Moreover, the most AEs in Thai patients who were treated with medical cannabis between cases and controls were tachycardia, arrhythmia, dry mouth, and nausea. Particularly, thirteen (72.22%) medical cannabis-induced AEs were female and age range 33 – 69 years. In this study, none of the medical cannabis groups carried *CYP2C9*2* variants in Thai patients. The *CYP2C9*3* variants (**1/*3*, intermediate metabolizer, IM) and (**3/*3*, poor metabolizer, PM) were found, three of thirty-nine (7.69%) and one of thirty-nine (2.56%), respectively. Although, our results indicate that there is no found the *CYP2C9*2*. However, the variation of *CYP2C9* allele might serve as a pharmacogenetics marker for screening before initiating the therapy with medical cannabis for prevention of medical cannabis-induced AEs.

Keywords: *CYP2C9*, Medical Cannabis, Adverse Effects, *THC*, *P450*

Fluid Dynamics perspective of Microbial Fuel Cells with Honey Comb Flow Straighteners

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Abstract:

The pursuit for alternate environmental-friendly energy sources is being established in the wake of environmental concerns like global warming and climate change. Microbial fuel cells (MFCs) are bio electrochemical transducers that can be used to produce electrical power under the activity of microbes during the wastewater treatment processes. Honey comb configurations or flow-straighteners are widely employed in fluid dynamics research works. They are advantageous due to the maintenance of a standardized and homogeneous fluid flow geometry inside a reactor, thereby reducing the turbulent fluid flow into laminar. These structures are used for achieving various targets like shear flow generation with homogenous and uniform flow geometry requiring low energy. The implementation of flow straighteners is an innovative idea in the field of MFCs and not many previous published literatures on honey comb MFCs are available. Flow parameters are very significant in bio electrochemical systems like MFCs and evaluation of their influences on the reactor performance is crucial. It is also very imperative to combine the field of fluid dynamics with MFCs for their future scaling up. Flow parameter investigation has been conducted in innovative flow straightener implemented honey comb MFCs (HCMFCs) in the current research study where the impacts of flow channel diameter on the performance of the reactors operated in recirculation batch mode have been estimated. Channel or pipe diameter is an important aspect to be considered in the field of flow dynamics. This can greatly influence the flow velocity and pattern of the fluid flowing inside in an optimistic manner. Along with that the effects of spacing between the anode and cathode electrodes on the reactors performance was also elucidated. Three reactors (HCMFC1, 2 and 3) with different channel diameters like 0.4 cm, 0.7 cm and 1 cm and electrode distances of 0, 3 and 6 cm were designed and operated along with a control reactor devoid of flow straighteners. Numerical simulation models were presented and analyses like Nyquist plots, polarization curves, power density curves and equivalent circuits were done. The HCMFC 2 reactor with 0.7 cm showcased the best performance by achieving a voltage generation of 0.55 V, current density of 5300 mA/m², power density of 430 mW/m², organic content removal of 97.6%, reduced internal resistance. Results showed that a higher limiting current density with 4108.7 mA/m² and a lower resistance with 2.51 Ω can be found in the case of the 0.0 cm electrode spacing. Result justification was accomplished by anode biofilm thickness analysis using scanning electron microscope. These results also indicated that the shorter electrode spacing with flow straightener devices would improve the performance of MFCs, leading to lower internal resistance and higher power density. The best performing reactors had the highest anode biofilm thickness which served as a proof for their heightened power production and treatment ability. These innovative flow straightener MFCs will effectively enhance research and provide great prospects for future applications. The current study is regarded as an enhancement attempt for the HCMFCs, where certain further aspects pertaining to flow dynamics, flow regime and velocity are being investigated using hydrodynamics aspects like Reynolds number and shear stress. Hence the present research work is an effective effort to reconnoiter the effects of flow parameters using CFDRC in HCMFCs and to also estimate their anode electrode biofilm thickness, organic content removal efficiency and power performance. This is strongly considered to be a successful frontward step that addresses the knowledge gap that requires to be accomplished and is definitely a scaling up progression for the performance enhancement of these novel MFC reactors.

Keywords: Electrode spacing, Flow straighteners, Honey comb microbial fuel cells, Hydraulic channel diameters, Numerical simulation, Wastewater Treatment

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Development of Broad Spectrum Nitrilase Biocatalysts and Bioprocesses for Nitrile Biotransformation

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Abstract— The enzymatic conversion of nitriles to carboxylic acids by nitrilases has gained significance in the green synthesis of several pharmaceutical precursors and fine chemicals. While nitrilases have been characterized from different sources, industrial application requires the identification of nitrilases that possess higher substrate tolerance, wider specificity and better thermostability, along with the development of an efficient bioprocess for producing large amounts of nitrilase.

To produce large amounts of nitrilase, we developed a fed-batch fermentation process on defined media for the high cell density cultivation of *E. coli* cells expressing the well-studied nitrilase from *Alcaligenes fecalis*. A DO-stat feeding approach was employed combined with optimized post-induction strategy to achieve nitrilase titer of 2.5×10^5 U/l and 78 g/l dry cell weight.

We also identified 16 novel nitrilase sequences from genome mining and analysis of substrate binding residues. The nitrilases were expressed in *E. coli* and their biocatalytic potential evaluated on a panel of 22 industrially relevant nitrile substrates using high-throughput screening and HPLC analysis. Nine nitrilases were identified to exhibit high activity on structurally diverse nitriles including aliphatic and aromatic dinitriles, heterocyclic, β -hydroxy and β -keto nitriles. With fed-batch biotransformation, whole cell *Zobelia galactanivorans* nitrilase achieved yields of 2.4 M nicotinic acid and 1.8 M isonicotinic acid from 3-cyanopyridine and 4-cyanopyridine respectively within 5 h, while *Cupravidus necator* nitrilase enantioselectively converted 740 mM mandelonitrile to (R)-mandelic acid. The nitrilase from *Achromobacter insolitus* could hydrolyze 542 mM iminodiacetonitrile in 1 h. The availability of highly active nitrilases along with bioprocesses for enzyme production expands the tool box for industrial biocatalysis.

Keywords— Biocatalysis, Isonicotinic acid, Iminodiacetic acid, Mandelic acid, Nitrilase

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Cybernetic Model-Based Optimization of a Fed-Batch Process for High Cell Density Cultivation of *E. Coli* in Shake Flasks

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Abstract— Batch cultivation of recombinant bacteria in shake flasks results in low cell density due to nutrient depletion. Previous protocols on high cell density cultivation in shake flasks have relied mainly on controlled release mechanisms and extended cultivation protocols. In the present work, we report an optimized fed-batch process for high cell density cultivation of recombinant *E. coli* BL21(DE3) for protein production. A cybernetic model-based, multi-objective optimization strategy was implemented to obtain the optimum operating variables to achieve maximum biomass and minimized substrate feed rate. A syringe pump was used to feed a mixture of glycerol and yeast extract into the shake flask. Preliminary experiments were conducted with online monitoring of dissolved oxygen (DO) and offline measurements of biomass and glycerol to estimate the model parameters. Multi-objective optimization was performed to obtain the pareto front surface. The selected optimized recipe was tested for a range of proteins that show different extent soluble expression in *E. coli*. These included *eYFP* and *LkADH*, which are largely expressed in soluble fraction, *CbFDH* and *GcanADH*, which are partially soluble, and human PDGF, which forms inclusion bodies. The biomass concentrations achieved in 24 h were in the range 19.9-21.5 g/L, while the model predicted value was 19.44 g/L. The process was successfully reproduced in a standard laboratory shake flask without online monitoring of DO and pH. The optimized fed-batch process showed significant improvement in both the biomass and protein production of the tested recombinant proteins compared to batch cultivation. The proposed process will have significant implications in the routine cultivation of *E. coli* for various applications.

Keywords— Cybernetic model, *E. coli*, High cell density cultivation, multi-objective optimization

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FWGE Production from Wheat Germ Using Co-Culture of *Saccharomyces Cerevisiae* and *Lactobacillus Plantarum*

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Abstract— food supplements are rich in specific nutrients and bioactive compounds that eliminate free radicals and improve cellular metabolism. The major bioactive compounds are found in bran and cereal sprouts. Secondary metabolites of these microorganisms have antioxidant properties that can be used alone or in combination with chemotherapy and radiation therapy to treat cancer. Biologically active compounds such as benzoquinone derivatives extracted from fermented wheat germ extract (FWGE) have several positive effects on the overall state of human health and strengthen the immune system. The present work describes the discontinuous fermentation of raw wheat germ for FWGE production through the simultaneous culture process using the probiotic strains of *Saccharomyces cerevisiae*, *Lactobacillus plantarum* and the possibility of using solid waste. To increase production efficiency, first to select important factors in the optimization of each fermentation process, using a factorial statistical scheme of stirring fraction (120 to 200 rpm), dilution of solids to solvent (1 to 8-12), fermentation time (16 to 24 hours) and strain to wheat germ ratio (20% to 50%) were studied and then simultaneous culture was performed to increase the yields of 2 and 6 dimethoxy benzoquinone (2,6-DMBQ). Since 2 and 6 dimethoxy benzoquinone were fermented as the main biologically active compound in wheat germ extract, UV-Vis analysis was performed to confirm the presence of 2 and 6 dimethoxy benzoquinone in the final product. In addition, 2,6-DMBQ of some products was isolated in a non-polar C-18 column and quantified using high performance liquid chromatography (HPLC). Based on our findings, it can be concluded that the increase of 2 and 6 dimethoxy benzoquinone in the simultaneous culture of *Saccharomyces cerevisiae* - *Lactobacillus plantarum* compared to pure culture of *Saccharomyces cerevisiae* (from 1.89 mg / g) to 28.9% (2.66 mg / g) increased.

Keywords— Wheat germ, FWGE, *Saccharomyces Cerevisiae*, *Lactobacillus Plantarum*, Co-culture, 2,6-DMBQ.

REFERENCES

- [1] Sun, Y., et al., Co-culture of *Aspergillus sydowii* and *Bacillus subtilis* induces the production of antibacterial metabolites. *Fungal Biology*, 2022.
 - [2] Rizzello, C.G., et al., Synthesis of 2-methoxy benzoquinone and 2, 6-dimethoxybenzoquinone by selected lactic acid bacteria during sourdough fermentation of wheat germ. *Microbial cell factories*, 2013. 12(1): p. 1-9.
 - [3] Zheng, Z., et al., The optimization of the fermentation process of wheat germ for flavonoids and two benzoquinones using EKF-ANN and NSGA-II. *RSC advances*, 2016.
 - [4] Parsazad, M., et al., Optimization of 2, 6-dimethoxy benzoquinone production through wheat germ fermentation by *saccharomyces cerevisiae*. *Applied Food Biotechnology*, 2020.
 - [5] [5] Zhang, J.-y., et al., Effect of fermented wheat germ extract with *lactobacillus plantarum* dy-1 on HT-29 cell proliferation and apoptosis. *Journal of Agricultural and Food Chemistry*, 2015.
 - [6] [6] Hu, J., et al., Anti-tumour immune effect of oral administration of *Lactobacillus plantarum* to CT26 tumour-bearing mice. *Journal of biosciences*, 2015. 40(2): p. 269-279.
 - [7] [7] Xie, C., et al., Co-fermentation of *Propionibacterium freudenreichii* and *Lactobacillus brevis* in Wheat Bran for in situ Production of Vitamin B12. *Frontiers in microbiology*, 2019.
 - [8] [8] Yoo, H., et al., Optimizing medium components for the maximum growth of *Lactobacillus plantarum* JNU 2116 using response surface methodology. *Korean journal for food science of animal resources*, 2018. 38(2): p. 240.
 - [9] [9] Marshall, M.R., Ash analysis, in *Food analysis*. 2010, Springer. p. 105-115.
 - [10] Wang, K., et al., Evaluation of biochemical and antioxidant dynamics during the co-fermentation of dehusked barley with *Rhizopus oryzae* and *Lactobacillus plantarum*. *Journal of Food Biochemistry*, 2020. 44(2): p. e13106.
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How Does Corruption Affect Sustainable Development? A Threshold Non-linear Analysis

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Abstract— Based on a panel data set of between 65 and 85 countries of different development levels for the period 1996-2019, this paper estimates a threshold model for different indicators of corruption and governance to contribute to the ongoing debate about whether corruption greases or sands the wheels of growth and Sustainable Development. The results reveal that, for the developed countries, corruption always hinders growth and Sustainable Development (no thresholds exist). However, for developing countries the results establish the existence of a significant threshold indicating that the impact of corruption on these three variables is a regime specific depending on the quality of governance. When the quality of governance is low, high corrupt countries achieve higher levels of economic growth, Sustainable Development, which is consistent with the “grease the wheel” hypothesis.

Keywords— Corruption, Governance, Sustainable development, Threshold models.

Brain Connectome of Glia, Axons, and Neurons: Cognitive Model of Analogy

Ozgu Hafizoglu

Abstract— An analogy is an essential tool of human cognition that enables connecting diffuse and diverse systems with physical, behavioral, principal relations that are essential to learning, discovery, and innovation. The Cognitive Model of Analogy (CMA) leads and creates patterns of pathways to transfer information within and between domains in science, just as happens in the brain. The connectome of the brain shows how the brain operates with mental leaps between domains and mental hops within domains and the way how analogical reasoning mechanism operates. This paper demonstrates the CMA as an evolutionary approach to science, technology, and life. The model puts forward the challenges of deep uncertainty about the future, emphasizing the need for flexibility of the system in order to enable reasoning methodology to adapt to changing conditions in the new era, especially post-pandemic. In this paper, we will reveal how to draw an analogy to scientific research to discover new systems that reveal the fractal schema of analogical reasoning within and between the systems like within and between the brain regions. Distinct phases of the problem-solving processes are divided thusly: stimulus, encoding, mapping, inference, and response. Based on the brain research so far, the system is revealed to be relevant to brain activation considering each of these phases with an emphasis on achieving a better visualization of the brain's mechanism in macro context; brain and spinal cord, and micro context: glia and neurons, relative to matching conditions of analogical reasoning and relational information, encoding, mapping, inference and response processes, and verification of perceptual responses in four-term analogical reasoning. Finally, we will relate all these terminologies with these mental leaps, mental maps, mental hops, and mental loops to make the mental model of CMA clear.

Keywords— analogy, analogical reasoning, brain connectome, cognitive model, neurons and glia, mental leaps, mental hops, mental loops.

The Social Origin Pay Gap in the UK Household Longitudinal Study

Michael Vallely

Abstract— This paper uses data from waves 1 to 10 (2009-2019) of the UK Household Longitudinal Study to examine the social origin pay gap in the UK labour market. We find that regardless of how we proxy social origin, whether it be using the dominance approach, total parental occupation, parental education, total parental education, or the higher parental occupation and higher parental education, the results have one thing in common; in all cases, we observe a significant social origin pay gap for those from the lower social origins with the largest pay gap observed for those from the ‘lowest’ social origin. The results may indicate that when we consider the occupational status and education of both parents, previous estimates of social origin pay gaps and the number of individuals affected may have been underestimated. We also observe social origin pay gaps within educational attainment groups, such as degree holders, and within professional and managerial occupations. Therefore, this paper makes a valuable contribution to the social origin pay gap literature as it provides empirical evidence of a social origin pay gap using a large-scale UK dataset and challenges the argument that education is the great ‘social leveller’.

Keywords— social class, social origin, pay gaps, wage inequality.

The Effectiveness of Using Plickers as a Formative Assessment Tool in English Foreign Language Classrooms

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Abstract— This study aims to analyse students' and teachers' perceptions of using Plickers as a formative assessment tool in EFL classrooms. The study implements a mixed methods approach. First, a questionnaire was administered to 64 students from two schools in Almadinah, a Saudi city. Then, in structured interviews, two English teachers provided their opinions on the advantages and disadvantages of integrating Plickers into their classrooms. The findings reveal that both teachers and students believe that using Plickers positively impacts students' learning. Moreover, the findings encourage teachers to integrate technology-based formative assessments in EFL classrooms. However, there are some drawbacks to using Plickers, such as technological issues. Finally, English teachers are recommended to engage all their students in a daily formative assessment by implementing Plickers in their classes.

Keywords— EFL classrooms, formative assessment, Plickers, technology, students,

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I. INTRODUCTION

EFFECTIVE Effective teachers always look for ways to measure instructional outcomes. One of these ways is the formative assessment, which is a main component of the learning process that gives teachers a clear picture of their students' progress and allows teachers to determine whether to continue with lessons or review missing skills [5]. Despite the importance of traditional formative assessments, such as written tests, such assessments take time as well as effort from teachers to check and assess. Therefore, it is difficult for teachers to apply additional formative assessments. However, the spread of technological tools, such as Plickers, eliminates this obstacle. Plickers is an online assessment software that allows teachers to collect data about their students' outcomes in seconds. Each student is given a card with

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a unique code to eliminate cheating. The teacher presents a multiple choice or true-or-false question, and students participate by raising their cards in response to indicate their answers. The teacher uses the application on his/her phone which is connected to the website through WIFI to scan the students' cards. The students' results immediately appear on the computer screen and are saved on the Plickers website.

After introducing Plickers, the article will introduce the literature review, followed by the study's purpose. Then, data and results will be represented, and finally, there will be pedagogical implications for teachers on using Plickers in the EFL classroom. Procedure for Paper Submission

II. LITERATURE REVIEW

A large and growing body of literature has investigated the importance of formative assessment in EFL classrooms. In general, these assessments positively impact students' performance and achievement [19]. A recent study conducted by [3] prove that the students who regularly received formative assessments on text comprehension improved more than the others, and they successfully completed tasks related to the text. One recent experiment shows that these assessments promote listening comprehension, as seen with the group that took advantage of the formative assessment during listening instruction and got high scores on listening tests [2]. It is worth noting that formative assessments not only affect student performance but also play a crucial role in motivating them and reducing their anxiety [1], [2]. Because of these benefits, many researchers insist on the use of

formative assessments as a part of daily instruction in EFL classrooms [3].

According to Ref. [8], there have been limitations to applying formative assessments, but they have decreased with the widespread use of technology tools in the 21st century. Indeed, most recent studies support the view that technology integration has lots of benefits in the educational sector. Technology-based classrooms not only increase student motivation but also encourage autonomy. Technology transforms the classroom into a student-centred learning environment, which puts the teacher into the role of facilitator and guide for the learning process [17]. Ref. [10] found a positive relationship between technology and students' engagement. This is in line with [11], [16].

Despite teachers' positive attitudes toward integrating technology in their classes, they believe that technology cannot guarantee the success of a learning process: it is the teacher's ability to implement an appropriate digital tool that determines better education [16]. Ref. [7] suggested that teachers have to consider use of technology tools when designing lessons.

One of the essential uses of digital tools is assessments in general and eventually in formative assessment. Research conclusively shows a relationship between technology use and application of formative assessments. Ref. [20] highlighted that digital tools such as Clickers, Kahoot, Plickers, and digital quizzes collect a large amount of data on students' understanding in a short time. This gives teachers a more formative assessment. Ref. [18] pointed out that technology makes checking and testing a daily routine. Furthermore, a recent study

found that using Clickers as Electronic Response System (ERS) positively affects participation. It also enhances students' self-esteem and lowers anxiety, since Clickers protect their autonomy [4]. In a similar vein, Ref. [19] found that using attractive tools for testing and assessment can motivate students.

As for using Plickers for formative assessments, there is a huge gap in the literature review focusing on implementing Plickers in EFL classes. However, in the few studies that presented Plickers, both teachers and students believe that it increases motivation and engagement [9], [12], [14]. It is a stress-free way to assess students in the EFL classroom [15]. However, teachers state that Plickers is limited to objective questions and sometimes presents technological problems [9]. Ref. [11] surveyed 50 high school students and found that the majority preferred using Plickers to a paper test, as it is easy to use. Nevertheless, there was no significant change to their recall questions and answers when using Plickers. This is in contrast to the results found by Ref. [13], which reported Kahoot helps students remember lessons. It is worth noting that Plickers reduces the possibility of cheating, since the cards can be read only by the electronic device [5]. However, this finding is in contrast to that of Ref. [12] which reported that students can easily read each other's answers. Plickers is used for formative assessment in other courses around the world, such as health and physical education [5] and algebra [6].

So far it could be summarized that there are few studies on Plickers as a tool for formative assessment in EFL classrooms [5], [12], [15]. To the best of the authors'

knowledge, there is only one study was conducted in AL-Bahrain by [9]. But no one is conducted in Kingdom of Saudi Arabia. Thus, this study identifies the impact of implementing Plickers as a formative assessment tool in EFL classrooms in Saudi Arabia.

III. PURPOSE AND RESEARCH QUESTIONS

This purpose of this study is to determine the perceptions of English teachers and students on using Plickers as an online formative assessment. It also aims to investigate Plickers' impact on students' learning and difficulties that teachers may face while using it. To achieve this aim, this study considers the following questions:

a- To what extent does Plickers as a formative assessment tool enhance students' learning in EFL classrooms?

b- Is there any challenges that teachers face while using Plickers?

IV. Methodology

a. Research Design

This study investigates the impact of implementing Plickers as a formative assessment to enhance students' learning. It employs a mixed research methods: quantitative, by using the means and standard deviations; and qualitative by analysing teachers' responses to the structured interviews.

b. Participants

The questionnaire was administered to 64 female (30 from third grade intermediate school and 34 from third grade secondary school) in Al-Madinah city which is located in the western region

of Saudi Arabia. Their ages ranged from 14 to 18 years. Two English teachers who implement Plickers in their classrooms, one from an intermediate school and the other from a secondary school, answered structured written interviews.

c. Instruments

The questionnaire used in this study is adapted from two studies conducted by Gürişik (2019) and Elmahdi et al. (2018). It is divided into three multi-item scales. The statements are rated on a Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree). The items were grouped into three subcategories during the data analysis:

1-Benefits of Plickers on student learning.

2-Students' engagement when using Plickers.

3-Students' enjoyment when using Plickers.

In addition, teachers were given written structured interviews with two open-ended questions. They were invented by the researcher on the advantages and disadvantages of implementing Plickers.

d. Data Analysis

The analysis of the quantitative data was done using the SPSS program (version 25) with descriptive statistical methods, such as means and standard deviation (M: 33.1406 and ST: 4.78). After the analysis, Cronbach Alpha value was examined to measure the internal consistency. The Cronbach Alpha reliability coefficient was .907 (see Appendix Table 4). Qualitative data were analysed through the content analysis method. Themes were created and used while analysing the qualitative data.

IV. RESULTS

A. Quantitative Data

The first category of the questionnaire includes four items, and the results are presented in Table 1 below. These items are 3, 5, 8, and 9. As the results show, the item 'I learn from my mistakes when Plickers show correct and incorrect answer instantly' has the highest mean score among other items with 3.41. Additionally, almost all of the students agreed that using Plickers makes them study harder (Item 3), with a mean of 3.19. Item 5 shows that the majority of students remember the Plickers questions and answers (Mean: 3.8). The last item of the category, 'Using Plickers is a waste of time', has the lowest mean score of 1.59.

TABLE 1
THE USEFULNESS OF USING PLICKERS ON STUDENT
LEARNING

Item	Mean	Std. Deviation	N
3-Using Plickers makes me study harder.	3.19	1.052	64
5-I remember questions and answers that I answered with Plickers	3.08	.948	64
8-Using Plickers is a waste of time	1.59	.955	64
9-I learn from my mistakes when Plickers show correct and incorrect answer instantly.	3.41	.904	64

The second category included three items that measure student engagement when using Plickers. As shown in Table 2 below, the item 'Plickers encourages me to participate in the class' has the highest score with a mean of 3.44. In addition,

TABLE2
STUDENT ENGAGEMENT WHEN USING PlickERS

Item	Mean	Std. Deviation	N
2-I feel comfortable in giving honest responses when teachers use Plickers.	3.27	.840	64
6-I feel nervous when my teacher uses Plickers.	1.95	1.015	64
7- Plickers encourages me to participate in the class.	3.44	.852	64

while most students feel comfortable using Plickers (Item 2, mean: 3.27), a few reported feeling nervous (Item: 6, mean: 1.95).

The third category is ‘The enjoyment of learning when students use Plickers’, which includes three items. As shown in Table 3, nearly all of the students agree that Plickers makes answering questions more fun (Item 1, mean: 3.44). A few state feeling bored when their teachers use Plickers (Item 4, mean: 1.42). The last item shows that most plan to use Plickers with their students when they become teachers, with a high mean of 3.30.

TABLE3
THE ENJOYMENT OF LEARNING WHEN STUDENTS USE PlickERS

Item	Mean	Std. Deviation	N
1-Plickers makes answering questions more fun.	3.44	.833	64
4-I feel bored when my teacher uses Plickers.	1.42	.708	64
10-I plan to use Plickers with my students when I become a teacher.	3.30	.954	64

B. Qualitative Data

The qualitative data were collected through written structured interviews with two questions. The first question is, ‘In your opinion, what are the benefits of using Plickers in your classroom?’ Indeed, both teachers believe that Plickers gives equal chances for all students to participate in the classroom. As for T1, she added:

One of the most advantages of using Plickers is that no one can cheat from other students since each paper is coded differently. Also, it allows me, as a teacher, to assess the students’ individually and in a short time.

T2 expressed her opinion by saying that:

What makes Plickers different from other technological tools is that students don’t need to have their own phones. Instead, they have coded paper to participate. This encourages me to use it in my class because it is forbidden for students to bring their phones in public schools.

The second question shed light on some of the drawbacks of using Plickers in EFL classrooms: ‘What challenges have you faced when using Plickers in your classrooms?’ The first teacher stated that Plickers needs strong Wi-Fi signal to work well. However, T2 commented, ‘‘One of the things that I don’t like about Plickers is that it is limited to objective questions, such as multiple choice and true or false statements.’’

V. DISCUSSION

The findings of this study will be discussed as follow. First, the findings of this support that Plickers enhances

learning. For instance, Ref. [15] found that Plickers is a free way to assess students. This is in line with what the students in this study state about the feeling of safe and relaxedness when they answer. Second, only a few of this study participants claim that using Plickers is boring. Most agree that it makes English classrooms more enjoyable. Various researchers from the literature supported this [9], [15]. Third, about two-third of the students, believe that Plickers helps them remember questions and answers. However, this finding is in contrast with [12] who reported that Kahoot has no effect on recall of questions and answers. Fourth, Plickers increases student engagement. This coincides with the findings of [10], [11], [16], that determined a positive relationship between technology and student engagement. Finally, in the open-ended questions, teachers reported that one of the most positive effects of integrating Plickers is that it gives them more chances to do formative assessments. This is in line with [18], [20] who stated that technology makes checking and testing a daily routine.

VI. PEDAGOGICAL RECOMMENDATIONS FOR EFL TEACHERS

These findings of this study lead to the following recommendations for EFL teachers. First, teachers should implement digital tools such as Plickers, Kahoot and Clickers to engage their students in daily formative assessments. Teachers are recommended to provide immediate feedback - which Plickers offers- to help their students correct misconceptions. Additionally, they can measure students' progress throughout the whole year, since the results are automatically saved on the website. As a last consideration, although using Plickers limits teachers to objective

questions, as the participants reported, the technique can still assess a variety of skills such as vocabulary, grammar, listening comprehension, and even reading comprehension. For example, after reading a text, teachers can use Plickers to assess their students' understanding.

VII. CONCLUSION

This study investigated the impact of using Plickers as a formative assessment for student learning in EFL classrooms. In general, both teachers and students agree that Plickers is an enjoyable and useful tool for formative assessment, as it motivates and engages students in the learning process. The main conclusion from this study is that Plickers enhances student learning. However, this conclusion cannot be generalized, because the instrument employed was a self-report questionnaire. This type of questionnaire can be criticized as not being a valid measurement of beliefs. Further studies may overcome this limitation to gain more valid results. Finally, future experimental studies could be applied to evaluate how the intervention of Plickers affects student achievement.

APPENDIX

TABLE 4
RELIABILITY STATISTICS

Cronbach's Alpha	Cronbach's Alpha Based on Standardized	
	Items	N of Items
.907	.908	10

REFERENCES

- [1] Baran-Lucarz, M. (2019). Formative assessment in the English as a foreign language classroom in secondary schools in Poland: Report on a mixed-method study. *The Journal of Education, Culture, and Society*, 10(2), 309-327. Doi: 10.15503/jecs20192.309.327

- [2] Bayat, A., Jamshidipour, A., & Hashemi, M. (2017). The beneficial impacts of applying formative assessment on Iranian university students' anxiety reduction and listening efficacy. *Online Submission*, 5(2), 1-11. doi: 10.18298/ijlet.1740
- [3] Boumediene, A., & Hamazaoui-Elachachi, H. (2017). The effects of formative assessment on Algerian secondary school pupils' text comprehension. *Arab World English Journal*, 8. Doi: <https://dx.doi.org/10.24093/awej/vol8no3.12>
- [4] Cakiroglu, U., Erdogdu, F., & Gokoglu, S. (2018). Clickers in EFL classrooms: Evidence from two different uses. *Contemporary Educational Technology*, 9(2), 171-185. <https://doi.org/10.30935/cet.414820>
- [5] Chng, L., & Gurvitch, R. (2018). Using Plickers as an assessment tool in health and physical education settings. *Journal of Physical Education, Recreation & Dance*, 89(2), 19-25. <https://doi.org/10.1080/07303084.2017.1404510>
- [6] Damick, J. M. (2015). Implementing technology in an algebra classroom. *Education and Human Development Master's Theses*. 622. https://digitalcommons.brockport.edu/ehd_theses/622
- [7] Dewi, F., Lengkanawati, N. S., & Purnawarman, P. (2019). Teachers' consideration in technology-integrated lesson design: A case of Indonesian EFL teachers. *International Journal of Emerging Technologies in Learning*, 14(18), 92-107. <https://doi.org/10.3991/ijet.v14i18.9806>
- [8] Ellis, C. (2013). Broadening the scope and increasing the usefulness of learning analytics: The case for assessment analytics. *British Journal of Educational Technology*, 44(4), 662-664. <https://doi.org/10.1111/bjet.12028>
- [9] Elmahdi, I., Al-Hattami, A., & Fawzi, H. (2018). Using technology for formative assessment to improve students' learning. *Turkish Online Journal of Educational Technology*, 17(2), 182-188. <https://www.researchgate.net/lab/Educational-Technology-Group-Ismail-Elmahdi>
- [10] Gebre, E., Saroyan, A., & Bracewell, R. (2014). Students' engagement in technology rich classrooms and its relationship to professors' conceptions of effective teaching. *British Journal of Educational Technology*, 45(1), 83-96. doi:10.1111/bjet.12001
- [11] Günüç, S., & Kuzu, A. (2014). Factors influencing student engagement and the role of technology in student engagement in higher education: Campus-class-technology theory. *Turkish Online Journal of Qualitative Inquiry*, 5(4), 86-113. DOI: 10.17569/tojqi.44261
- [12] GÜRIŞİK, A., & DEMİRKAN, Ö. (2019). Opinions of high school students about Plickers: One of the online formative assessment tools. *International Journal of Scientific Research and Innovative Technology*, 6(1). ISSN: 2313-3759
- [13] Iwamoto, D. H., Hargis, J., Taitano, E. J., & Vuong, K. (2017). Analyzing the efficacy of the testing effect using KAHOOTTM on student performance. *Turkish Online Journal of Distance Education*, 18(2), 80-93. ISSN 1302-6488
- [14] Kent, D. (2019). Plickers and the pedagogical practicality of fast formative assessment. *Teaching English with Technology*, 19(3), 90-104. <http://www.tewtjournal.org/>
- [15] Michael, E. A., Ejeng, I. E. A., Udit, M. A., & Yunus, M. M. (2019). The use of Plickers for language assessment of reading comprehension. *International Journal of Academic Research and Social Sciences*, 9(1) DOI: 10.6007/IJARSS/v9-i1/5464
- [16] Mollaei, F., & Riasati, M. J. (2013). Teachers' perceptions of using technology in teaching EFL. *International Journal of Applied Linguistics and English Literature*, 2(1), 13-22. doi:10.7575/ijalel.v2n1p13
- [17] Morera Trasierra, M. (2018). The use of technology in EFL classrooms: Advantages and disadvantages. <http://hdl.handle.net/10854/5540>
- [18] Nguyen, T. T. T., & Yukawa, T. (2019). Kahoot with smartphones in testing and assessment of language teaching and learning, the need of training on mobile devices for Vietnamese teachers and students. *International Journal of Information and Education Technology*, 9(4). DOI: 10.18178/ijiet.2019.9.4.1214
- [19] Ozan, C., & Kincal, R. Y. (2018). The effects of formative assessment on academic achievement, attitudes toward the lesson, and self-regulation skills. *Educational Sciences: Theory and Practice*, 18(1), 85-118. DOI: 10.12738/estp.2018.1.0216
- [20] Ramsey, B., & Duffy, A. (2016). Formative assessment in the classroom: Findings from three districts. Michael and Susan Dell Foundation and Education, 1. <https://education-first.com/library/publication/formative-assessment-in-the-classroom/>

Presence and Severity of Language Deficits in Comprehension, Production and Pragmatics in a Group of ALS Patients: Analysis with Demographic and Neuropsychological Data

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Abstract. Background. Amyotrophic Lateral Sclerosis (ALS) is a neurodegenerative disease of adulthood, which primarily affects the central nervous system and is characterized by progressive bilateral degeneration of motor neurons. The degeneration processes in ALS extend far beyond the neurons of the motor system, and affects cognition, behaviour and language. Aims. To outline the prevalence of language deficits in an ALS cohort and explore their profile along with demographic and neuropsychological data.

Methods. A full neuropsychological battery and language assessment was administered to 56 ALS patients. Neuropsychological assessment included tests of executive functioning, verbal fluency, social cognition and memory. Language was assessed using tests for verbal comprehension, production and pragmatics. Patients were cognitively classified following the Revised Consensus Criteria and divided in three groups showing different levels of language deficits: group 1 - no language deficit; group 2 - one language deficit; group 3 - two or more language deficits. Chi-square for independence and non-parametric measures to compare groups were applied.

Results. Nearly half of ALS-CN patients (48%) reported one language test under the clinical cut-off, and only 13% of patents classified as ALS-CI showed no language deficits, while the rest 87% of ALS-CI reported two or more language deficits. ALS-BI and ALS-CBI cases all reported two or more language deficits. Deficits in production and in comprehension appeared more frequent in ALS-CI patients ($p=0.011$, $p=0.003$ respectively), with a higher percentage of comprehension deficits (83%). Nearly all ALS-CI reported at least one deficit in pragmatic abilities (96%) and all ALS-BI and ALS-CBI patients showed pragmatic deficits. Males showed higher percentage of pragmatic deficits (97%, $p=0.007$). No significant differences in language deficits have been found between bulbar and spinal onset. Months from onset and level of impairment at testing (ALS-FRS total score) were not significantly different between levels and type of language impairment. Age and education were significantly higher for cases showing no deficits in comprehension and pragmatics and in the group showing no language deficits. Comparing performances at neuropsychological tests among the three levels of language deficits, no significant differences in neuropsychological performances were found between group 1 and 2; compared to group 1, group 3 appeared to decay specifically on executive testing, verbal/visuospatial learning, and social cognition. Compared to group 2, group 3 showed worse performances specifically in tests of working memory and attention.

Conclusions. Language deficits have found to be spread in our sample, encompassing verbal comprehension, production and pragmatics. Our study reveals that also cognitive intact patients (ALS-CN) showed at least one language deficit in 48% of cases. Pragmatic domain is the most compromised (84% of the total sample), present in nearly all ALS-CI (96%), likely due to the influence of executive impairment. Lower age and higher

education seem to preserve comprehension, pragmatics and presence of language deficits. Finally, executive functions, verbal/visuospatial learning and social cognition differentiate the group with no language deficits from the group with a clinical language impairment (group 3), while attention and working memory differentiate the group with one language deficit from the clinical impaired group.

Keywords: Amyotrophic Lateral Sclerosis – Language assessment – Neuropsychological assessment – Language deficit

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Discovering Word-Class Deficits in Persons with Aphasia

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Abstract— Aim: The current study aims at discovering word-class deficits concerning the noun-verb ratio in confrontation naming, picture description, and picture-word matching tasks. A total of ten persons with aphasia (PWA) and ten age-matched neurotypical individuals (NTI) were recruited for the study. The research includes both behavioural and objective measures to assess the word class deficits in PWA. Objective: The main objective of the research is to identify word class deficits seen in persons with aphasia, using various speech eliciting tasks. Method: The study was conducted in the L1 of the participants, considered to be Kannada. Action naming test and Boston naming test adapted to the Kannada version are administered to the participants; also, a picture description task is carried out. Picture-word matching task was carried out using e-prime software (version 2) to measure the accuracy and reaction time with respect to identification verbs and nouns. The stimulus was presented through auditory and visual modes. Data were analysed to identify errors noticed in the naming of nouns versus verbs, with respect to the Boston naming test and action naming test and also usage of nouns and verbs in the picture description task. Reaction time and accuracy for picture-word matching were extracted from the software. Results: PWA showed a significant difference in sentence structure compared to age-matched NTI. Also, PWA showed impairment in syntactic measures in the picture description task, with fewer correct grammatical sentences and fewer correct usage of verbs and nouns, and they produced a greater proportion of nouns compared to verbs. PWA had poorer accuracy and lesser reaction time in the picture-word matching task compared to NTI, and accuracy was higher for nouns compared to verbs in PWA. The deficits were noticed irrespective of the cause leading to aphasia.

Keywords— nouns, verbs, aphasia, naming, description.

Internalization of Environmental Credits from Ammonia Synthesis By-Products in Life Cycle Assessments

Jose Osorio-Tejada, Nam N. Tran, Volker Hessel

Abstract— Ammonia is an indispensable feedstock for agriculture, which besides its use as fertilizer, it has been recently used as hydrogen carrier given its ease for storage and transport. The most common pathway is the Haber-Bosch (HB) process, based on steam methane reforming, releasing high amounts of carbon emissions. In addition, given that this process highly depends on non-expensive natural gas, ammonia production is concentrated in few countries at large-scale plants, adding emissions due to transportation. Small-scale plants next to farmers can reduce these impacts, as well as reduce large storage needs, shortage risks and price volatility of imported fertilizers, promote local employment and bespoke production. Mini HB plants and non-thermal plasma reactors have been proposed, which can feasibly use cleaner technologies to produce the hydrogen feedstock, such as water electrolysis or thermal plasma methane pyrolysis. However, these technologies consume high quantities of electricity, increasing emissions when electricity is produced from fossil sources. This electricity consumption also makes these alternatives more expensive than the conventional ammonia pathway. Although, besides ammonia, these proposed routes can produce valuable by-products such as oxygen, carbon black and steam, which can improve their cost-effectiveness and reduce the life cycle impacts of ammonia production. The feasibility of these emerging technologies can be promoted by the internalization of environmental benefits of its products life cycles in their economic analyses. In this sense, the life cycle assessment methodology is applied to different ammonia production pathways in order to quantify, from cradle-to-utilization, credits of avoided emissions in the production, storage and transportation phases, by-products utilization, use of local renewable resources, reduction of product wastes, and soil beneficitation. Different scenarios are analyzed for centralized and distributed ammonia production in Australia for the conventional large-scale HB process, alternatives using mini-HB reactor supplied by hydrogen from water electrolysis and thermal plasma methane pyrolysis, and the non-thermal plasma-assisted synthesis supplied by water electrolysis, using

different renewable energy sources according to the location. Since the alternative routes such as plasma-assisted ammonia production has been only tested at lab scales, and the mini HB at pilot plants, the material and energy flows are obtained from scaled-up modelling in Aspen Plus and the life cycle impacts assessment modelled in SimaPro 9 using the ReCiPe method to analyze burdens on climate change, ozone formation, water eutrophication, soil acidification, land use, and toxicity on soils, water and humans. The best energy sources and plant configurations for each environmental impact category would be identified and their characterized results monetized and internalized in life cycle costing analyses for each alternative, which can contribute to the deployment of distributed green ammonia production in regions where the use of ammonia from the conventional route is neither sustainable nor profitable to supply the agricultural sector.

Keywords— Plasma, LCA, fertilizers, Haber-Bosch.

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Assessing Circularity Potentials and Customer Education to Drive Ecologically and Economically Effective Materials Design for Circular Economy - A Case Study

Mateusz Wielopolski, Asia Guerreschi

Abstract— Circular Economy, as the counterargument to the ‘make-take-dispose’ linear model, is an approach that includes a variety of schools of thought looking at environmental, economic, and social sustainability. This, in turn, leads to a variety of strategies and often confusion when it comes to choosing the right one to make a circular transition as effective as possible. Due to the close interplay of circular product design, business model and social responsibility, companies often struggle to develop strategies that comply with all three triple-bottom-line criteria. Hence, to transition to circularity effectively, product design approaches must become more inclusive. In a case study conducted with the University of Bayreuth and the ISPO, we correlated aspects of material choice in product design, labeling and technological innovation with customer preferences and education about specific material and technology features. The study revealed those attributes of the consumers’ environmental awareness that directly translate into an increase of purchase power - primarily connected with individual preferences regarding sports activity and technical knowledge. Based on this outcome, we constituted a product development approach that incorporates the consumers’ individual preferences towards sustainable product features as well as their awareness about materials and technology. It allows deploying targeted customer education campaigns to raise the willingness to pay for sustainability. Next, we implemented the customer preference and education analysis into a circularity assessment tool that takes into account inherent company assets as well as subjective parameters like customer awareness. The outcome is a detailed but not cumbersome scoring system, which provides guidance for material and technology choices for circular product design while considering business model and communication strategy to the attentive customers. By including customer knowledge and complying with corresponding labels, companies develop more effective circular design strategies, while simultaneously increasing customers’ trust and loyalty.

Keywords— circularity, sustainability, product design, material choice, education, awareness, willingness to pay.

Relationships between Actors within Business Ecosystems that Adopt Circular Strategies: A Systematic Literature Review

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Abstract—The circular economy (CE) aims at the cycling of resources through restorative and regenerative strategies. To achieve circularity, coordination of several actors who have different responsibilities is necessary. The interaction among multiple actors allows the connection between the CE and business ecosystem research fields. Although fundamental, the relationships between actors within an ecosystem to foster circularity is not deeply explored in the literature. The objective of this study was to identify the possibilities of cooperation, competition, or even cooptation among the members of business ecosystems that adopt circular strategies. In particular, the motivations that make these actors interact to achieve a circular economy were investigated. A systematic literature review was adopted to select business ecosystem cases that adopt circular strategies. As a result, several motivations were identified for actors to engage in relationships within ecosystems, such as sharing knowledge and infrastructure, developing products with a circular design, promoting reverse logistics, among others. The results suggest that partnerships between actors are, in fact, important for the implementation of circular strategies. In order to achieve a complete and circular solution, actors must be able to clearly understand their roles and relationships within the network so that they can establish new partnerships or reframe those already established.

Keywords—Business ecosystem, circular economy, cooperation, cooptation, competition.

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Good Advice is Hard to Come by! A Cross-Cultural Perspective on Opposing Views and Entrepreneurial Passion

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PRINCIPAL TOPIC

Passion is considered one of the most important motivating factors for entrepreneurship (Schumpeter & Redvers, 1934; Thurik & Wennekers, 2004). Entrepreneurship is often marked by complexity and challenges, but it is not necessarily a lonely journey (Miron-Spektor et al., 2018). Entrepreneurs depend on support (Howard et al., 2019) due to a lack of experience with basic organizational processes and limited resources (Stinchcombe, 1965). The importance of external support is even greater in developing and emerging economies, where conditions differ significantly from those in advanced economies and where the degree of resource scarcity is even more severe (Charmes et al., 2018). Entrepreneurs can receive such external support from various stakeholders like mentors, partners, investors and customers (Guerrero & Espinoza-Benavides, 2021; Mason & Brown, 2014). These stakeholders reduce environmental uncertainty by providing entrepreneurs and young companies access to capital, knowledge, and other resources (Shane & Cable, 2002).

Nevertheless, the existence of support is no guarantee that entrepreneurs are also able to take advantage of them. Rather, it largely depends on the entrepreneurs and their abilities to be receptive to external help (Barham et al., 2018), to consciously expose themselves to external feedback (Hart et al., 2009), and to evaluate this feedback objectively (Lord et al., 1979). Individuals have specific values and perceptions of reality, which significantly influence their decisions and motivations (Dawson et al., 2002). This can lead to friction and defensive reactions when the external feedback contradicts the entrepreneur's own views (Minson et al., 2020). The

However, entrepreneurship research lacks the perspective of the influence of individuals' receptiveness to external feedback (e.g., opposing views) which is, nevertheless, necessary for leveraging external support and thus fostering entrepreneurial passion (Guerrero & Espinoza-Benavides, 2021). According to self-determination theory (SDT), this is an issue since the confrontation with contrary opinions threatens an individual's autonomy in their activities, resulting in lower motivation levels (Ryan & Deci, 2000). Thus, the purpose of this study is to understand the *impact of entrepreneurs' receptiveness to opposing views on their entrepreneurial passion*.

We contribute to the literature and practice in three ways: First, we address the call from entrepreneurship scholars to focus research efforts more on the under-researched determinants of entrepreneurial passion (e.g., Murnieks et al., 2020; Newman et al., 2019). A better understanding of the origin of entrepreneurial passion may help to identify important implications for subsequent entrepreneurial behavior (Cardon et al., 2012; Murnieks et al., 2014). Second, we introduce the construct of *receptiveness to opposing views* into the entrepreneurship domain and SDT. This is an extension of SDT in a growing area of the entrepreneurship domain (Singh & Ashraf, 2020). Third, we also extend the existing passion literature by introducing a new moderator related to *access to information* (Spreitzer, 1996). Individuals evaluate new information based on their existing knowledge. Consistent with SDT, we, therefore, assume a positive influence of *access to information* on the main relationship studied. Practitioners will benefit from our insights on seeking and accepting advice or focusing on their own ideas and vision.

METHODOLOGY

Following a cross-cultural approach, we surveyed entrepreneurs in seven developing and emerging economies. All respondents are self-reported active entrepreneurs from Colombia, Ghana, Iran, Iraq, Kenya, Nigeria, and the Philippines. The selection of these seven countries followed a structured methodology to ensure sampling frame equivalence (Engelen et al., 2016) and a maximum of cultural and geographical diversity (Bosma et al., 2020). Translation-equivalence was achieved by established translation and back-translation procedures for each language (Hult et al., 2008). To avoid single source bias, we contacted participants through multiple channels (Foo et al., 2009). These channels have been adapted according to local conditions in each country and include chambers of commerce among other government agencies, local associations, professional social media platforms, universities, and other non-governmental organizations (Gielnik et al., 2015).

Our online survey was sent via Qualtrics to 2,440 entrepreneurs, of whom 1,228 completed the survey yielding a response rate of 50%. After excluding incomplete responses, the final sample size is 1,061, almost evenly distributed across the seven target countries.

Vallerand *et al.*'s (2003) seven-item *passion* scale was adapted to the context of entrepreneurship. Harmonious passion have been shown to work well in cross-cultural and entrepreneurship research settings (e.g., Schellenberg et al., 2016). The 18-item *receptiveness to opposing views* scale was based on Minson et al. (2020). Our moderator *access to information* measure was based on the social structural characteristics scale (Spreitzer, 1996). We controlled for individual-level and firm-level characteristics that prior research showed influence passion (Ho & Pollack, 2014; Vallerand et al., 2003).

RESULTS

Hierarchical regression modeling is used to test our hypothesis. As hypothesized and consistent with SDT, our initial results indicate a positive relationship between *receptiveness to opposing views* and *harmonious passion for entrepreneurship*. Furthermore, we found first empirical evidence for a significant moderating effect of *access to information* that reinforces the positive main effect.

Our unique cross-cultural data set includes national and cultural variables as well as value-related variables, the study of which can provide exciting findings on additional moderating relationships beyond the traditional boundaries of entrepreneurship research. We evaluate the model fit with further (factor) analyses, tests, and robustness checks and ensure that common method variance (e.g., anonymity of respondents, marker variable tests, separation of IV and DV) is not a problem. The statistical analyses are expected to be completed by December 2021.

BIBLIOGRAPHY

- Barham, B. L., Chavas, J. P., Fitz, D., & Schechter, L. (2018). Receptiveness to advice, cognitive ability, and technology adoption. *Journal of Economic Behavior and Organization*, 149, 239–268. <https://doi.org/10.1016/j.jebo.2017.12.025>
- Bosma, N., Hill, S., Ionescu-Somers, A., Kelley, D., Levie, J., & Tarnawa, A. (2020). *GEM - Global entrepreneurship monitor*.
- Cardon, M. S., Foo, M. Der, Shepherd, D., & Wiklund, J. (2012). Exploring the Heart: Entrepreneurial emotion is a hot topic. *Entrepreneurship: Theory and Practice*, 36(1), 1–10. <https://doi.org/10.1111/j.1540-6520.2011.00501.x>
- Charmes, J., Gault, F., & Wunsch-Vincent, S. (2018). Measuring innovation in the informal economy – formulating an agenda for Africa. *Journal of Intellectual Capital*, 19(3), 536–549.

<https://doi.org/10.1108/JIC-11-2016-0126>

- Dawson, E., Gilovich, T., & Regan, D. T. (2002). Motivated reasoning and performance on the wason selection task. *Personality and Social Psychology Bulletin*, 28(10), 1379–1387. <https://doi.org/10.1177/014616702236869>
- Engelen, A., Engelen, M., & Craig, C. S. (2016). Challenges in Conducting International Market Research. In *Handbook of Market Research*. Springer International Publishing AG 2016. https://doi.org/10.1007/978-3-319-05542-8_6-1
- Foo, M. Der, Uy, M. A., & Baron, R. A. (2009). How Do Feelings Influence Effort? An Empirical Study of Entrepreneurs' Affect and Venture Effort. *Journal of Applied Psychology*, 94(4), 1086–1094. <https://doi.org/10.1037/a0015599>
- Gielnik, M. M., Spitzmuller, M., Schmitt, A., Klemann, D. K., & Frese, M. (2015). “I put in effort, therefore I am passionate”: Investigating the path from effort to passion in entrepreneurship. *Academy of Management Journal*, 58(4), 1012–1031. <https://doi.org/10.5465/amj.2011.0727>
- Guerrero, M., & Espinoza-Benavides, J. (2021). Does entrepreneurship ecosystem influence business re-entries after failure? *International Entrepreneurship and Management Journal*, 17(1), 211–227. <https://doi.org/10.1007/s11365-020-00694-7>
- Hart, W., Albarracín, D., Eagly, A. H., Brechan, I., Lindberg, M. J., & Merrill, L. (2009). Feeling Validated Versus Being Correct: A Meta-Analysis of Selective Exposure to Information. *Psychological Bulletin*, 135(4), 555–588. <https://doi.org/10.1037/a0015701>
- Ho, V. T., & Pollack, J. M. (2014). Passion isn't always a good thing: Examining entrepreneurs' network centrality and financial performance with a dualistic model of passion. *Journal of Management Studies*, 51(3), 433–459. <https://doi.org/10.1111/joms.12062>
- Howard, M. D., Boeker, W., & Andrus, J. L. (2019). The spawning of ecosystems: How cohort effects benefit new ventures. *Academy of Management Journal*, 62(4), 1163–1193. <https://doi.org/10.5465/amj.2016.1248>
- Hult, G. T. M., Ketchen, D. J., Griffith, D. A., Finnegan, C. A., Gonzalez-Padron, T., Harmancioglu, N., Huang, Y., Talay, M. B., & Cavusgil, S. T. (2008). Data equivalence in cross-cultural international business research: Assessment and guidelines. *Journal of International Business Studies*, 39(6), 1027–1044. <https://doi.org/10.1057/palgrave.jibs.8400396>
- Lord, C. G., Ross, L., & Lepper, M. R. (1979). Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology*, 37(11), 2098–2109. <https://doi.org/10.1037/0022-3514.37.11.2098>
- Mason, C., & Brown, R. (2014). ENTREPRENEURIAL ECOSYSTEMS AND GROWTH ORIENTED ENTREPRENEURSHIP. In *Paper prepared for a workshop of the OECD LEED Programme and the Dutch Ministry of Economic Affairs*.
- Minson, J. A., Chen, F. S., & Tinsley, C. H. (2020). Why won't you listen to me? Measuring receptiveness to opposing views. *Management Science*, 66(7), 3069–3094. <https://doi.org/10.1287/mnsc.2019.3362>
- Miron-Spektor, E., Ingram, A., Keller, J., Smith, W. K., & Lewis, M. W. (2018). Microfoundations of organizational paradox: The problem is how we think about the problem. *Academy of Management Journal*, 61(1), 26–45. <https://doi.org/10.5465/amj.2016.0594>
- Murnieks, C. Y., Klotz, A. C., & Shepherd, D. A. (2020). Entrepreneurial motivation: A review of the literature and an agenda for future research. *Journal of Organizational Behavior*, 41(2), 115–143. <https://doi.org/10.1002/job.2374>

- Murnieks, C. Y., Mosakowski, E., & Cardon, M. S. (2014). Pathways of Passion: Identity Centrality, Passion, and Behavior Among Entrepreneurs. *Journal of Management*, 40(6), 1583–1606. <https://doi.org/10.1177/0149206311433855>
- Newman, A., Obschonka, M., Moeller, J., & Chandan, G. G. (2019). Entrepreneurial Passion: A Review, Synthesis, and Agenda for Future Research. *Applied Psychology*, 0(0), 1–45. <https://doi.org/10.1111/apps.12236>
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68–78. <https://doi.org/10.1037/0003-066X.55.1.68>
- Schellenberg, B. J. I., Bailis, D. S., & Mosewich, A. D. (2016). You have passion, but do you have self-compassion? Harmonious passion, obsessive passion, and responses to passion-related failure. *Personality and Individual Differences*, 99, 278–285. <https://doi.org/10.1016/J.PAID.2016.05.003>
- Schumpeter, J. A., & Redvers, O. (1934). *The theory of economic development; an inquiry into profits, capital, credit, interest, and the business cycle*. Harvard University Press.
- Shane, S., & Cable, D. (2002). Network ties, reputation, and the financing of new ventures. *Management Science*, 48(3), 364–381. <https://doi.org/10.1287/mnsc.48.3.364.7731>
- Singh, A. K., & Ashraf, S. N. (2020). Association of Entrepreneurship Ecosystem with Economic Growth in Selected Countries: An Empirical Exploration | Journal of Entrepreneurship, Business and Economics. *Journal of Entrepreneurship, Business and Economics*, October, 36–92. <http://scientificia.com/index.php/JEBE/article/view/138>
- Spreitzer, G. M. (1996). Social structural characteristics of psychological empowerment. *Academy of Management Journal*, 39(2), 483–504. <https://doi.org/10.2307/256789>
- Stinchcombe, A. L. (1965). Social Structure and Organizations. In *Handbook of organizations* (pp. 142–193). Bobbs-Merrill. [https://doi.org/10.1016/S0742-3322\(00\)17019-6](https://doi.org/10.1016/S0742-3322(00)17019-6)
- Thurik, R., & Wennekers, S. (2004). Entrepreneurship, small business and economic growth. *Journal of Small Business and Enterprise Development*, 11(1), 140–149. <https://doi.org/10.1108/14626000410519173>
- Vallerand, R. J., Mageau, G. A., Ratelle, C., Léonard, M., Blanchard, C., Koestner, R., Gagné, M., & Marsolais, J. (2003). Les Passions de l'Âme: On Obsessive and Harmonious Passion. *Journal of Personality and Social Psychology*, 85(4), 756–767. <https://doi.org/10.1037/0022-3514.85.4.756>

Sustainability Communications Across Multi-Stakeholder Groups: A Critical Review of the Findings from the Hospitality and Tourism Sectors

Frederica Pettit

Abstract— Contribution: Stakeholder involvement in CSR is essential to ensuring pro-environmental attitudes and behaviours across multi-stakeholder groups. Despite increased awareness of the benefits surrounding a collaborative approach to sustainability communications, its success is limited by difficulties engaging with active online conversations with stakeholder groups. Whilst previous research defines the effectiveness of sustainability communications; this paper contributes to knowledge through the development of a theoretical framework that explores the processes to achieving pro-environmental attitudes and behaviours in stakeholder groups. The research will also consider social media as an opportunity to communicate CSR information to all stakeholder groups. Approach: A systematic review was chosen to investigate the effectiveness of the types of sustainability communications used in the hospitality and tourism industries. The systematic review was completed using Web of Science and Scopus using the search terms “sustainab* communicat*” “effective or effectiveness,” and “hospitality or tourism,” limiting the results to peer-reviewed research. 133 abstracts were initially read, with articles being excluded for irrelevance, duplicated articles, non-empirical studies, and language. A total of 45 papers were included as part of the systematic review. 5 propositions were created based on the results of the systematic review, helping to develop a theoretical framework of the processes needed for companies to encourage pro-environmental behaviours across multi-stakeholder groups. Results: The theoretical framework developed in the paper determined the processes necessary for companies to achieve pro-environmental behaviours in stakeholders. The processes to achieving pro-environmental attitudes and behaviours are stakeholder-focused, identifying the need for communications to be specific to their targeted audience. Collaborative communications that enable stakeholders to engage with CSR information and provide feedback lead to a higher awareness of CSR shared visions and pro-environmental attitudes and behaviours. These processes should also aim to improve their relationships with stakeholders through transparency of CSR, CSR strategies that match stakeholder values and ethics whilst prioritizing sustainability as part of their job role. Alternatively, companies can prioritize pro-environmental behaviours using choice editing by mainstreaming sustainability as the only option. In recent years, there has been extensive research on social media as a viable source of sustainability communications, with benefits including direct interactions with stakeholders, the ability to enforce the authenticity of CSR activities and encouragement of pro-environmental behaviours. Despite this, there are challenges to implementing CSR, including difficulties controlling stakeholder criticisms, negative stakeholder influences and comments left on social media platforms. Conclusion: A lack of engagement with CSR information is a reoccurring reason for preventing pro-environmental attitudes and behaviours across stakeholder groups. Traditional CSR strategies contribute to this due to their inability to engage with their intended audience. Hospitality and tourism companies are improving stakeholder relationships through collaborative processes which reduce single-use plastic consumption. A collaborative approach to communications can lead

to stakeholder satisfaction, leading to changes in attitudes and behaviours. Different sources of communications are accessed by different stakeholder groups, identifying the need for targeted sustainability messaging, creating benefits such as direct interactions with stakeholders, the ability to enforce the authenticity of CSR activities, and encouraging engagement with sustainability information.

Keywords— hospitality, pro-environmental attitudes and behaviours, sustainability communication, social media.

Circular Economy in Social Practice in Response to Social Needs: Community Actions Versus Government Policy

Sai-Kit Choi

Abstract— While traditional social services heavily depended on Government funding and support, there were always time lag, and resources mismatch with the fast growing and changing social needs. This study aims at investigating the effectiveness of implementing Circular Economy concept in a social service setting with comparison to Government Policy in response to social needs in 3 areas: response time, suitability, and community participation. To investigate the effectiveness of implementing Circular Economy concept in a social service setting, a real service model, a community resources sharing platform, was set up and statistics of the first 6 months' operation data were used as comparison with traditional social services. Literature review was conducted as a reference basis of traditional social services under Government Policy. Case studies were conducted to provide the qualitative perspectives of the innovative approach. The results suggest that the Circular Economy model showed extraordinarily high level of community participation. In addition, it could utilize community resources in response precisely to the burning social needs. On the other hand, the available resources were unstable when comparing to those services supported by Government funding. The research team concluded that Circular Economy has high potential in applications in social service, especially in certain areas, such as resources sharing platform. Notwithstanding, it should be aware of the stability of resources when the services targeted to support some crucial needs.

Keywords— circular economy, social innovation, community participation, sharing economy, social response.

The Effect of Gender and Resources on Entrepreneurial Activity

Frederick Wedzerai Nyakudya¹

Abstract

In this paper, we examine the relationship between human capital, personal wealth and social capital to explain the differences in start-up rates between female and male entrepreneurs. Since our dependent variable is dichotomous, we examine the determinants of these using a maximum likelihood logit estimator. We used the Global Entrepreneurship Monitor database covering the period 2006 to 2009 with 421 usable cases drawn from the Lower Layer Super Output Areas in East Midlands in the United Kingdom. We found evidence that indicate that a female positively moderate the positive relationships between indicators of human capital and personal wealth with start-up activity. The findings have implications for programs, policies, and practices to encourage more females to engage in start-up activity.

Keywords: Entrepreneurship; Start-up; GEM; Gender gap; Women's entrepreneurship

1. Introduction

Creation of new firms has been important, both during periods of economic downturn, and in times of prosperity. New firms can be a source of economic growth, innovation and employment opportunities, and they apply competitive pressure on incumbent firms which enhances efficiency and favours consumers [1], [2], [3]. Hence, engagement in start-up activities is considered to be a method of promoting upward social mobility which is one of the key outcome of entrepreneurial success [4], [5]. Thus, promotion of new business creation has remained a key agenda item for the economic development policy of most developed and developing nations around the globe [6], [7].

Prior studies suggest that potential entrepreneurs possess unique capabilities that help in recognising new business opportunities in the environment and assembling of appropriate resources that facilitate in the creation of new businesses especially if they can manage the resources effectively [8], [9], [10] [11]. However, this literature has paid little attention to individual level characteristics that may influence how they manage their resources and succeed in starting a new business. To our best knowledge, a limited number of studies have investigated why certain individuals were more effective than others in leveraging their financial, human and social capital to succeed in creating a new firm. Given the importance of small businesses, the significant growth in the numbers of females engaged in entrepreneurship, the rising scholarly interest in gender and existing evidence showing that

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female and male entrepreneurs manage their resources differently and often achieve different economic outcomes [12], [13], it is important to understand the distinctiveness of female start-ups.

Evidence from 43 countries participating in Global Entrepreneurship Monitor (GEM) surveys indicate that over 252 million women were actively engaged in the process of starting a new business and 153 million women were owners of established businesses [14]. However, the literature indicate that there are significant variations on the rate of entrepreneurial activity between countries [14], [15]. For example, within high income economies, the gender gap of the adult working population between 18-64 engaged in early stage entrepreneurial activity varied significantly from 9 percent for male and 6.1 percent female in the United Kingdom (UK), 5.1 percent male and 4.4 percent female in Germany and 17.3 percent male and 13.6 percent female in United States (US). The literature has identified some of the possible factors affecting these cross country differences in start-up rates [16], [17], [18].

Moreover, we posit that the effect of the context is best understood at the neighbourhood level, yet, to our best knowledge, the start-ups have not yet been investigated in that way. It is also important to explain the gaps in detail since how we intend to explore them will define our contribution.

The first gap in the literature is that country level studies distinguish between environmental and individual effects [19], [20]. There is limited evidence of this approach being applied at the local or neighbourhood level. Since there is significant variation in entrepreneurship rates between and within countries such an analysis at the neighbourhood level may help in enriching our understanding of the role of the individual level attributes, resource endowments and neighbourhood level resources combine to influence entry into entrepreneurial activity [21], [22].

Therefore, the first objective of this study is to examine whether, and to which extent, both the individual level resource endowments and the resources in the neighbourhood environment combine to influence an individual's decision to engage in the start-up activity. To this effect, we draw on the resource-based theory (RBT) [23]. Studies based on RBT emphasise on the different dimensions of the components without considering coherence and interactions between them. The goal of this research is to apply the RBT, not only comparing their relative strengths but also elucidating their reciprocal interactions in an analytical framework.

Second, making a distinction between the individual level and the neighbourhood characteristics enables us to precisely define the neighbourhood environment using the Lower Layer Super Output Areas (LSOA) as the appropriate spatial units where people live and interact in a socio-economic sense [24]. Focusing on variations in social networks at the neighbourhood level and to reduce extraneous spatial variations, East Midlands region was chosen as representative of the UK assuming that at the regional level, cultural and historical dimensions remain similar [25], [26], [27].

In the next section we provide a discussion about our theoretical framework and how it may help in explaining why some but not all individuals engage in start-up present hypotheses. This is followed by a discussion relating to the database we have used and the methods employed. We present the results of the logistic regressions. Finally, this is followed by a discussion of the findings including managerial and policy implications.

2. Theoretical framework, previous literature and hypotheses

Over time, heterogeneous distribution of resources and capabilities among individuals living in the same environment resulted in entrepreneurship being implicitly associated with

men and characterised as masculinity. This self-reinforcing nature of the process of entrepreneurial activity was defined by [28] as the outcome of a hierarchical system in which a dominant group maintains control over the distribution of resources and considered as more legitimate. These resources and capabilities possessed by this group of individuals are considered to be inimitable, rare and valuable and are not traded freely on the market [29], [9], [10], [11].

This conceptualisation forms the basis of the resource based theory of entrepreneurship (RBT) which explains why some individuals but not all engage in entrepreneurship [23]. It assumes that potential entrepreneurs have unique capabilities that enable them to identify new business opportunities and also facilitate in assembling appropriate resources required for creating a new business [30], [31]. Hence, this perspective assumes that entrepreneurs can increase the value of their resources through effective management to reduce the cost of resources utilised in the entrepreneurial process [32], [33], [34]. Thus, recent studies suggest individual differences among entrepreneurs are likely to influence the effect of resource endowments on their propensity to engage in entrepreneurial activity [35], [36], [37].

Although this study employs the RBT, it acknowledges that minimal attention has been paid to the role that gender plays in the decision to engage in entrepreneurial activity. Even those studies that succeed in including women in their sample usually use a dummy variable to determine gender differences without considering the gender based interactions [38] [39], [40]. Such interactions might have implications for how male and female entrepreneurs employ their financial, human and social capital to achieve the desired entrepreneurial outcomes. The objective of this study is not only to examine the influence of resources and capabilities on entrepreneurial activity but also to elucidate their reciprocal interactions with gender in the analytical framework.

This study has several significant advantages over previous studies. A more relevant definition of entrepreneurial activity was implemented using the information available in the GEM database used. Thus, individuals are defined as entrepreneurs if they have started a business which employs one or more people (start-up) at the time of survey as opposed to the conventional self-employment. From this base, the study demonstrates that using start-up as an outcome measure reduces or eliminates selection bias and over or underestimation of the combined effect of gender, resources and capabilities on entrepreneurial activity. In addition to the correction of biases, the analysis enabled a close assessment of the effect of resources by employing detailed information on personal and family wealth.

2.1. Financial capital

Financial capital can increase the propensity to become an entrepreneur (or self-employed) but this effect may differ between male and female entrepreneurs. This section focuses on the importance of the financial markets as providers of financial capital [41], [39], [17], because of the growing entrepreneurship literature on personal and family wealth [42], [43], [44] and the inconclusive findings concerning whether and under what conditions would access to financial capital and wealth influence entrepreneurial activity. The seminal work by [39] was among the first to recognise the importance of wealth for entrepreneurship. The subsequent literature expanded this work from different perspectives and this study focuses on two streams of literature.

The first stream of the literature focused on understanding the influence of financial markets on entrepreneurship. A well-developed financial market ensures that entrepreneurs have good access to the market and are able to get the required capital. It is also assumed that lower levels of personal wealth restricted access to credit making it difficult for entrepreneurs to cover start-up costs and reduced their chances of starting a new business. In developed economies with well developed financial markets it is less likely that financial constraints

will apply. However, it appears as if, even in developed economies, entrepreneurs often have idiosyncratic knowledge about the market potential of their entrepreneurial projects and that made it difficult to be assessed by external providers of finance such as banks. This may also lead to an increase in the cost of borrowing or constraints in financing the entrepreneurial activities [45]. Therefore, individuals with lower levels of wealth are less likely to be able to compensate for the lack of external capital with their own resources and this may limit their chances of starting a new venture or result in undercapitalisation [46], [47].

The second stream of studies focused on the importance of individual or family wealth for entrepreneurial activity [42], [43], [48]. These studies have shown that the positive association between wealth and the propensity to start a new business was much stronger for the wealthy individuals and/or households. They argued that borrowing constraints were less likely to have an impact on entrepreneurial activities of the low-wealthy individuals and/or households. Since individuals or households at the top end of the wealth distribution are less likely to have their entrepreneurial activities affected by financial constraints, they infer the positive relationship between wealth and entrepreneurial activity as extremely wealthy individuals having stronger preferences for becoming entrepreneurs than those with lower levels of wealth. This group is drawn by non-pecuniary perks such as greater need for personal autonomy and flexible working conditions resulting in entrepreneurship being viewed as an appealing occupational choice [42].

Consistent with the discussion above, it has been shown that liquidity constraints differ by gender. It has been shown that an increase in wealth had a strong positive effect on the propensity of women to start a business in Germany [17]. A similar result has also been found for the UK [18]. These findings suggest that females might have specific advantages in managing financial capital. The literature teaches us that females are more disciplined, less over-confident and adhere to stricter ethical practices than males [12], [49], [50]. It has been recognised that females are more likely to judge questionable business practices unethical [51] and this was supported by [52] who show that females tend to assess their investment opportunities more accurately and males often overestimate theirs.

Taken together, the arguments suggest that financial capital should be positively associated with entrepreneurial activity and this relationship should be stronger for females. Drawing on the above discussion the following hypothesis:

Hypothesis 1: An entrepreneur's gender positively moderates the relationship between financial capital and the probability of becoming an entrepreneur and this positive relationship should be much stronger for female entrepreneurs.

2.2. Human capital and entrepreneurship

Human capital refers to the knowledge, skills and perceptions that increases an individual's effectiveness in performing his/her duties and can be purchased at a cost [18], [53]. These are often acquired through formal education and work experience; however, an entrepreneur's human capital can be a critical differentiator among the male and female entrepreneurs. For this reason, the RBT considers human capital as a critical resource that entrepreneurs possess because when new business opportunities emerge, individuals with higher levels of human are, on average, more likely to identify and exploit them than those with lower levels of human capital [23], [54]. Formal education and work experience are the main components of human capital which may or may not represent knowledge and

skills required to undertake tasks related to the starting a new business [53]. Evidence suggests that high levels of human capital are positively associated with entry into entrepreneurship [55], [56], [57]. Others drew on GEM data from 41 countries and examined a range of human capital variable and find that prior experience, formal education and self efficacy (defined as perceived knowledge and skills required to start a business) is positively associated with engagement in entrepreneurial activity [58]. Thus, human capital can represent objective elements that can be observed such as formal education or subjective elements that are internal such as perceived knowledge and skills. Based on the discussion above, this study focuses on three key components of human capital relevant to new business start-up: formal education and work experience and self efficacy.

Prior studies provide several theoretical and empirical arguments about how education might influence entry into entrepreneurship. Evidence suggests that individuals who are highly educated often have a strong knowledge base and cognitive skills which allow them to solve complex problems [59], [53] and increases their effectiveness in performing entrepreneurial tasks [60], [61], [55]. Others suggest that education increases curiosity, openness to new ideas, receptive to innovation and change [62], [63], [64]. These attributes can increase their willingness to engage in entrepreneurial activity, ability to identify, understand and to act on information relating to new opportunities. Knowledge can also help to compensate for the lack of financial resources [40] or acquire other resources such as physical and financial capital [65]. Several studies find that high levels of education were positively associated with the likelihood to start a new business [43], [56], [55].

Likewise, work experience can offer learning opportunities that facilitate entrepreneurs in developing routines and heuristics to identify and evaluate new business opportunities, assemble resources to exploit opportunities and enable them to act quickly [66]. Evidence suggest that unemployed people are more likely to engage in entrepreneurial activity due to lack of suitable employment opportunities [66]. This is linked to the push motive which can be defined as negative circumstances which force individuals to start businesses [67]. Therefore, transition into entrepreneurship is more likely to higher for those who are not in employment and they can be in a hurry to start their business because of lack of suitable employment opportunities in the labour market [40]. In contrast, individuals attempt to get compensation for their investment in human capital [68]. Thus, highly educated individuals may find entrepreneurship less appealing if it leads to reduced income compared to that from current employment. But, if those with higher levels of human capital engage in entrepreneurship, they are more likely to be successful [69].

Although formal education and prior experience can be considered as generic resources required when starting a new business, entrepreneurial specific skills, matters too [56]. Entrepreneurial specific human capital is defined as the knowledge and skills that facilitate in setting up a new business [70]. It has been recognised that perceptions of one's capabilities and skills influences action in such a way that the more an individual believe that he/she has the required knowledge and skills required to start a business the more likely he/she is more likely to choose entrepreneurship as a viable career choice [71]. Evidence suggest that higher levels of confidence in beliefs about an individual's ability to pursue entrepreneurial career can influence start-up activities [72]. Moreover perceived capabilities are correlated with beliefs relating to the attractiveness of the business opportunity may or may not be acquired through formal education [73].

The literature that examined gendered start up rates show mixed results of the various socialisation experience such as affiliation with social network and work experience. In support, studies demonstrate that when education and work experience are homogenously distributed among men and women, there would not be a significant gender difference among entrepreneurs [74]. This suggests that gender equality in education and work experience is

associated with equality in entrepreneurship rates. Evidence suggests that education, in particular entrepreneurial education play a major role in the development of entrepreneurial self efficacy for women than men [16], [75], [76] but we have limited understand about whether the impact of self efficacy on start up rates differs by gender.

In line with the arguments presented above, we argue that female entrepreneurs might have some attributes that facilitate in managing human capital. Evidence suggest that females possess more transformational leadership attributes and higher rates of empowering management [77]. Therefore, we argue that a relational perspective may help female entrepreneurs to develop more collaborative relationships with various stakeholders and better relationships facilitate their ability to leverage human capital by promoting smoother information flow. Moreover, evidence suggests that transformational leadership plays an important role in increasing commitment, interpersonal interactions, fosters innovation and enhances performance [78], [79], [80]. Therefore, human capital should facilitate entrepreneurs in identifying, evaluating and exploiting new opportunities and female entrepreneurs might have superior ability to gather the knowledge, skills and talent required to create a new firm.

Based on this discussion, the arguments suggest that an individual's human capital measured by education, prior experience and perceptions of ability are positively related to the probability of becoming an entrepreneur and this relationship is stronger for female entrepreneurs than male entrepreneurs. As a result, the following hypotheses are proposed:

Hypothesis 2a: An entrepreneur's gender positively moderates the relationship between education and the probability of becoming an entrepreneur and this positive relationship should be much stronger for female entrepreneurs.

Hypothesis 2b: An entrepreneur's gender positively moderates the relationship between individuals who are employed and the probability of becoming an entrepreneur and this relationship should be much stronger for male entrepreneurs.

Hypothesis 2c: An entrepreneur's gender positively moderates the relationship between individuals with higher levels of entrepreneurial specific knowledge and skills, and the probability of becoming an entrepreneur and this positive relationship should be much stronger for female entrepreneurs.

2.3. Social capital and entrepreneurship

The discussion above focused on the individual characteristics of would-be entrepreneurs. However, the neighbourhood social environment may also have a significant influence on an individual's decision to engage in start-up activities. The social environment is often considered as social network relationships. Thus, social capital can be defined as networks of relationships were personal and organisational contacts are often closely embedded. These relationships are considers as means through which members gain access to a wide range of resources possessed by other actors [24], [81]. Notably, the networks are more likely to enhance the entrepreneur's human capital by facilitating individuals in identifying opportunities, acquiring resources and development of an entrepreneurial spirit. This social network approach to understanding the role of social capital in entrepreneurship is based on

[82] study that made a distinction between strong and weak ties [83]. Literature suggest that networks characterised by frequently repeated homogenous social interactions are labelled as ‘strong ties’ [84]. But if entrepreneurs are weakly connected to others and have little emotional engagement, these relationships can be defined as ‘weak ties’ [82]. These offer different benefits and expect them to play different roles in an individual’s decision to become an entrepreneur. However, weak ties may provide access to wider and diverse knowledge base that may facilitate entrepreneurial activity. If the profile of the neighbourhood exhibits entrepreneurial traits, they determine the opportunities for individuals to form entrepreneurship specific weak ties that may enhance their chances to engage in entrepreneurship. From this perspective the term entrepreneurship capital was used to define a “specific type of social capital as a regional milieu of agents that explicitly generates” entry into entrepreneurial activity by making the neighbourhood environment rich with explicit or implicit knowledge and entrepreneurship specific resources [21], [22]. It is assumed that such a milieu creates both role models and network opportunities based on weak ties that are important for entrepreneurship. Previous studies suggests that weak ties are strongly associated with entrepreneurship relevant information and tangible capital [85, 86]. Likewise, others argued that regions with a higher density of entrepreneurship facilitate the creation of new firms [21]. Both weak and strong ties were found to be good predictors for male and female entry into entrepreneurial activity [87]. Evidence suggests that there should no difference on the effect of strong ties on an individual’s decision to become an entrepreneur between the male and female entrepreneurs [88]. In contrast, McGowan and Hampton [89] provided evidence which show that female entrepreneurs had lower rates of weak ties than the male counterparts. Based on this line of thought we propose the following hypotheses:

Hypothesis 3a: An entrepreneur’s gender positively moderates the relationship between the density of established owner-managers of businesses in the local neighbourhood and the probability of becoming an entrepreneur and this positive relationship should be much stronger for male entrepreneurs.

Hypothesis 3b: An entrepreneur’s gender positively moderates the relationship between the density of individual who know successful entrepreneurs in the local neighbourhood and the probability of becoming an entrepreneur and this positive relationship should be much stronger for male entrepreneurs.

3. Methodology

3.1. Databases

In this study, the combined 2007 English Index of Multiple Deprivation database and the 2006 to 2009 UK GEM East Midlands region databases was used to test the hypotheses. The individual level data was drawn from the GEM database which consists of random samples, stratified by region, of the working age population contacted by telephone random dialling techniques by a professional marketing company [90]. After accounting for missing data in the variables we use, that resulted in an effective sample size of 421 usable cases (see Table 3 below).

3.2. Dependent variable

The dependent variable is actual engagement in nascent entrepreneurial activity [90], which we use as a proxy for entry into entrepreneurship. It includes individuals who have been

involved creating a new business during the previous year, expect to own the whole of a share of the new firm and have paid wages and salaries for a period not exceeding forty-two months. The focus is two alternative methods of entry into entrepreneurship available to entrepreneurs: self-employment or start-up. Start-up is when an individual create a new business which employs one or more people excluding the owner. Self-employed are individuals who start a firm which does not employ other people (often referred to as solo-traders). Thus, the dependent variable take the value of 1 if an individual start a business which employ others and 0 if she or he is self-employed.

3.3. Individual level predictors and controls

Our first predictor variable, *wealth* (H1), is measured by categorical variable and quintiles 1 represent the lowest level of wealth to 5 as highest level of wealth. Following [91] this study use the residential address of the participant as a measure of wealth which is closely related to an individual's financial position, observable and requires no input from them. Several studies have used housing as a predictor variable to investigate the impact of wealth on entry into entrepreneurship [92], [93], [94] or on labour mobility [91]. Evidence suggest that there is a very strong correlation between housing and income [91]. The residential address also set the bases for UK official survey data relating to mortgage repayments and rents. Moreover it has been recognised that individuals or households with higher levels of income spend more on housing and the same applies when property is rented due to the close relationship between ranking of the asset value and rental costs. The official measure of the community's level of socio-economic development in England is the English Index of Multiple Deprivation (IMD) and its component indicators for 2,732 Lower Layer Super Output Areas (LSOA), communities with an average population of 1,500 people [95]. To link the IMD to residential addresses, we were able to classify each respondent in the East Midlands into their LSOA, by inputting postcode data into the Geo-Convert facility. Then, we ranked each respondent according to their local community's level of socio-economic development which is expressed in quintiles from 1 being the most deprived to 5 as the least deprived areas. By grouping the sample into quintiles, we defined deprived areas as those LSOA located in the lowest 20% of all the LSOAs.

The second predictor variable, *highest educational attainment* (H2a), is measured by a categorical variable denoting, 1 as individuals with no formal education to 6 as individuals with a master and doctorate qualification. The third predictor variable, *prior work experience* (H2b), is a dummy variable and is equal to 1 if an individual is in employment and 0 otherwise. The fourth predictor variable is also a dummy variable, *self-assessed knowledge and skills specific to entrepreneurship* (H2c), is equal to 1 if an individual believe that he/she has the relevant knowledge and skills required to start a new firm and 0 otherwise.

In addition, our moderator variable, *gender*, is equal to 1 if the individual is female and 0 if male. Prior studies have shown that females possess some attributes which facilitate them to leverage their human, financial and social capital to achieve economic outcomes or engage in entrepreneurship [12], [17], [96].

Finally, we included a number of controls at the individual level: age, fear of failure, good opportunities in the local area, business premises, being an owner manager of an already existing business, and personally knowing other entrepreneurs which have all been shown to affect an individual's propensity to engage in entrepreneurial activity [94, 97, 98].

3.4. Neighbourhood level predictors and controls

Several studies have shown that the local environment matters for entrepreneurship [99], [100], [101]. Others have indicated that deprived areas have social networks related to bonding capital and strong ties limit access to both tangible and intangible resources [102]. Therefore, in our specifications we include two dimensions neighbourhood level predictors. These variables relate to our hypotheses include *the share of owner managers of established businesses more than 42 months old in the local neighbourhood (H3a)* and *the share of individuals who personally know other successful entrepreneurs in the neighbourhood (H3b)*. In addition, we include fixed effects related to the higher-level territorial units, which are East Midlands Counties, and an indicator variable representing urban versus rural areas (at LSOA level). Table 1a and 1b below provides the description of the variables used in this study. In Table 2 below, we present the correlation coefficients for the variables used in the regressions are presented in Table 2 below. The coefficients are relatively low, thus, issues related to multicollinearity which may require further analysis are not anticipated.

Table1a: Description of categorical variables (at the individual level)

Variable	Description	Percentage
Dependent variable (Early stage entrepreneurial activity)		
Start-up	1 if respondent is an entrepreneur and employs one or more people	32.78
	0 if self employed and no employees	67.22
Predictors		
Female	1 if female	59.35
	0 otherwise	40.65
Wealth	Categorical variable: based on individual's postcode.	
	Wealth: Q1, Lowest value assets (base category)	11.82
	Wealth: Q2	17.16
	Wealth: Q3	20.62
	Wealth: Q4	22.19
Wealth: Q5: Highest value assets	28.21	
Education	Categorical variable for educational attainment	
	1 if respondent has no formal qualifications (base category)	15.91
	2 if respondent has GCSE qualification	25.82
	3 if respondent has A level qualification	19.41
	4 if respondent has Vocational and others qualifications	12.30
	5 if respondent has Bachelor degree qualification	19.55
6 if respondent has Post graduate qualification	7.01	
Knowledge & skills	1 if individual believe that he/she has the necessary knowledge and skills required in starting a new business	31.83
	0 Otherwise	68.17
In Employment	1 if respondent was employed	74.07
	0 otherwise	25.93
Controls		
Age	The exact age at the time of interview	
	0 if respondent is over 45 years old	52.85
	1 If respondent's age is below 46 years	47.15
Knowing entrepreneurs	1 if respondent personally knows someone who started a business in the past 2 years	14.72
	0 otherwise	85.28
Business owners	1 if owner-manager of an existing business	8.65
	0 otherwise	91.35
Fear of failure	1 if respondent was afraid to start a business in case it might fail	20.08
	0 otherwise	79.92
Business angels	1 if respondent was a business angel in past 3 years	1.19
	0 otherwise	98.81
Good opportunities	1 if respondent sees good opportunities in his/her local area	15.90
	0 otherwise	84.10
Urban areas	1 if Lower Super OutPut Areas (LSOA)is in an urban area	67.22

	0 if Lower LSOA is in a rural area	32.78
Counties	Categorical variable for East Midlands Counties	
	1. Derbyshire	24.24
	2. Leicestershire	21.17
	3. Lincolnshire	17.28
	4. Northamptonshire	14.63
	5. Nottinghamshire	22.69

Table1b: Description of continuous variables (at the LSOA level)

Variable	Description	Mean	St.dev.	Range
<i>Predictors</i>				
Share of knowing entrepreneurs	Prevalence rate of respondents who personally knew nascent entrepreneurs, in last 2 years: rate based on LSOA mean	0.240	0.228	0 - 1
Share of business owners	Prevalence rate of owner-managers of established businesses over 42 months old: rate based LSOA mean	0.239	0.240	0 - 1

Table 2: Correlations: Spearman rho correlation coefficients for individual level and neighbourhood characteristics

	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Start-up	0	1	1													
2. Gender: Female	0	1	-0.06	1												
3. Wealth	1	5	0.09	-0.09	1											
4. Education	1	6	0.04	-0.03	-0.10	1										
5. Knowledge and skills	0	1	0.03	-0.14	-0.03	0.03	1									
6. In employment	0	1	-0.14	-0.05	0.03	0.01	0.06	1								
7. Age	0	1	0.08	0.05	0.20	-0.05	-0.01	0.07	1							
8. Knowing entrepreneurs	0	1	0.13	-0.14	0.03	0.09	0.09	0.09	0.08	1						
9. Business owners	0	1	-0.32	-0.16	-0.02	0.06	0.12	0.20	-0.02	-0.01	1					
10. Fear of failure	0	1	0.01	0.09	0.03	0.01	-0.17	0.04	0.04	-0.07	-0.01	1				
11. Business premise	0	1	0.32	-0.06	-0.01	-0.02	0.03	0.03	0.11	0.08	-0.17	-0.06	1			
12. Good opportunities	0	1	0.23	0.03	0.06	0.13	0.06	-0.02	0.14	0.17	-0.12	-0.15	0.05	1		
13. Urban areas	0	1	0.08	-0.09	0.44	-0.07	-0.07	0.03	0.12	0.06	-0.04	0.03	0.00	0.01	1	
14. East Midlands counties	1	5	0.06	0.13	0.07	-0.02	-0.01	0.02	0.07	0.01	0.06	0.01	-0.01	0.04	-0.00	1

3.1 Estimation Strategy

We apply a maximum likelihood logit estimator to predict the probability of an individual to engage in entrepreneurial activity. Following prior work [103] our model is constructed as follows:

$$y_{ij}^* = \gamma x_{ij} + \varepsilon_i,$$

$$y_{ij} = 1 \text{ if } y_{ij}^* > 0, \text{ and } 0 \text{ otherwise.}$$

Where i relates to individual characteristics and j refer to neighbourhood characteristics. In turn y as referring to observed entry into entrepreneurial activity which is a dummy variable where 1 represents actual engagement in starting a new firm. In contrast, y^* represents the unobserved utility of entrepreneurial activity with a mean at zero. Here the predictors and control variables are shown by matrix x with a vector of coefficients γ and we use all the variables listed in Table 1a and 1b above. In turn, ε refers to unobserved, individual specific heterogeneity, which is assumed to be unrelated to x . Assuming that a cumulative distribution of the error term is logistic delivers the maximum likelihood logit estimator that we employed. Finally, in the results section, we will present odds ratios instead of coefficients since they are easier to interpret.

Since our dependent variable is dichotomous, a logistic regression is appropriate. To account for the non-independence of observations within the same neighbourhood, we cluster the standard errors by LSOA. This deals with the issue relating to the possibility that individuals residing in the same neighbourhood are more likely to have similar characteristics, resources and capabilities that may differentiate them from others residing in other neighbourhoods. If such correlations are not addressed, it may result in a violation of one of the key classical assumption of regression models. In addition, multicollinearity was found not to be an issue since that the minimum tolerance is 0.5430 and the highest VIF is 2.07, indicate a weak relationship among the variables. Since all the variables do not have a tolerance below 0.1 and a VIF >10 there would be no need for further investigation [104].

Before we present the results, measures of the explanatory power and diagnostics of all the models are presented in Table 3. Table 3 reports the results of logistic regression for our models assessing entry into start-up activity. Model 1 reports the effects of all the control variables and Model 2 we added all the predictor variables. Models 3 to 5 we add the interactions between *wealth*, *highest educational attainment*, *prior work experience*, *knowledge and skills specific to entrepreneurship*, *share of owner managers of established businesses more than 42 months old in the local neighbourhood* and *share of individuals who personally know other successful entrepreneurs in the neighbourhood* with *gender* respectively. Finally, Model 6 presents our full model, reports the main effects including interactions. We supplement these by reporting results of additional tests; we present visual illustration of the hypothesised effects and interpret the marginal effects.

3. Results

The maximum likelihood estimation results are presented in Table 3 below. We supplement these results by reporting results of additional tests, comparing coefficients across different outcomes and with some graphic illustration of the results. Table 3 reports the logistic regression results for our models examining entry into start-up activity. Model 1 presents the

effects of the control variables. Model 2 reports the effects of our key variables. Based on Model 2, the results indicate higher levels of wealth (with the exception of ‘Wealth Q4’) above Wealth Q1, increases the probability of entry into entrepreneurial activity. The coefficient for all the categories of formal education including entrepreneurial specific knowledge and skills are not significant. Being in employment is negative and significant at 1%. The coefficient for the share of business owners in the neighbourhood is positive and significant at 5% level. However, the coefficient for the share of individuals who know entrepreneurs in their neighbourhood is negative and significant at 5% level. Perhaps the most interesting is the coefficient for female which is negative and significant at 5% level indicating that female are less likely to start a new business than their male counterparts.

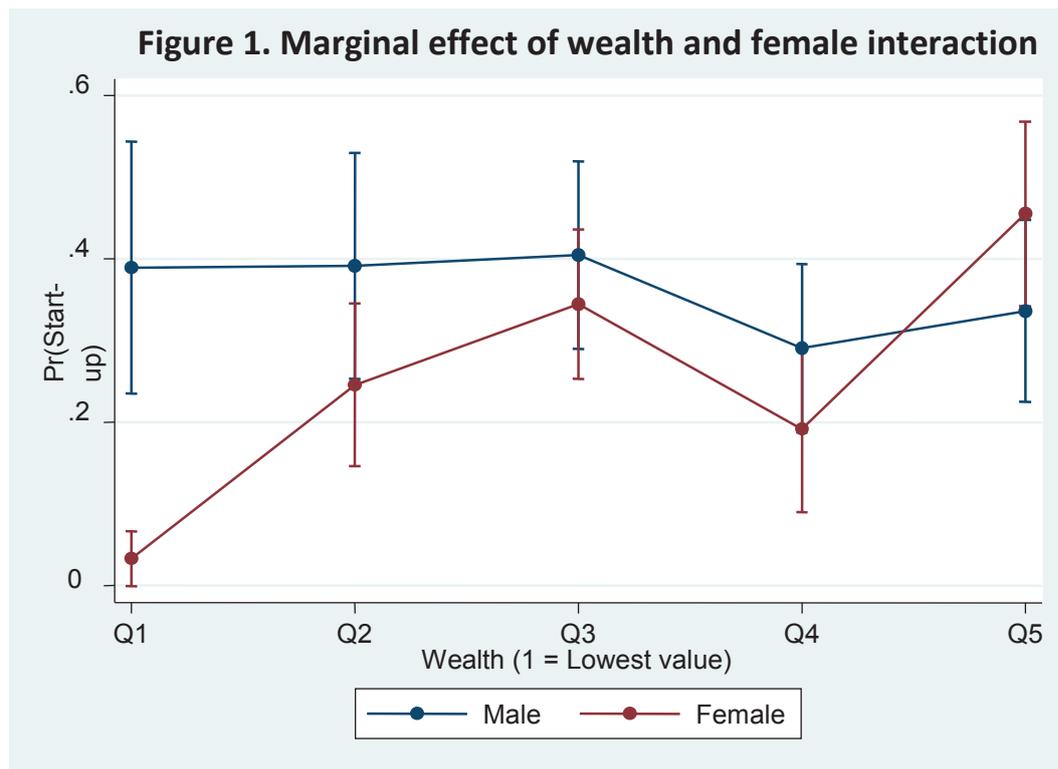
In Hypothesis 1, we argue that female entrepreneur positively moderates the effect of financial capital on becoming an entrepreneur. The results indicate that the interaction of higher levels of wealth in both Model 3 and Model 6 are positive and statistically significant. Although higher levels of wealth increase the probability of females to start a new firm, the magnitude of the effects vary from 5 percent for Q2 and Q4, and 1 percent for Q3 and Q5 in both models. We also examined the marginal effects of wealth on start-up activities. Likewise, Figure 1 above show that at the lowest level of wealth, female probability of starting a new business is around 3 percent while male probability is around 39 percent. Moreover, the lower limit of each 95% confidence interval is clearly above zero, therefore,

Table 3: Logistic regression models explaining likelihood of start-up.

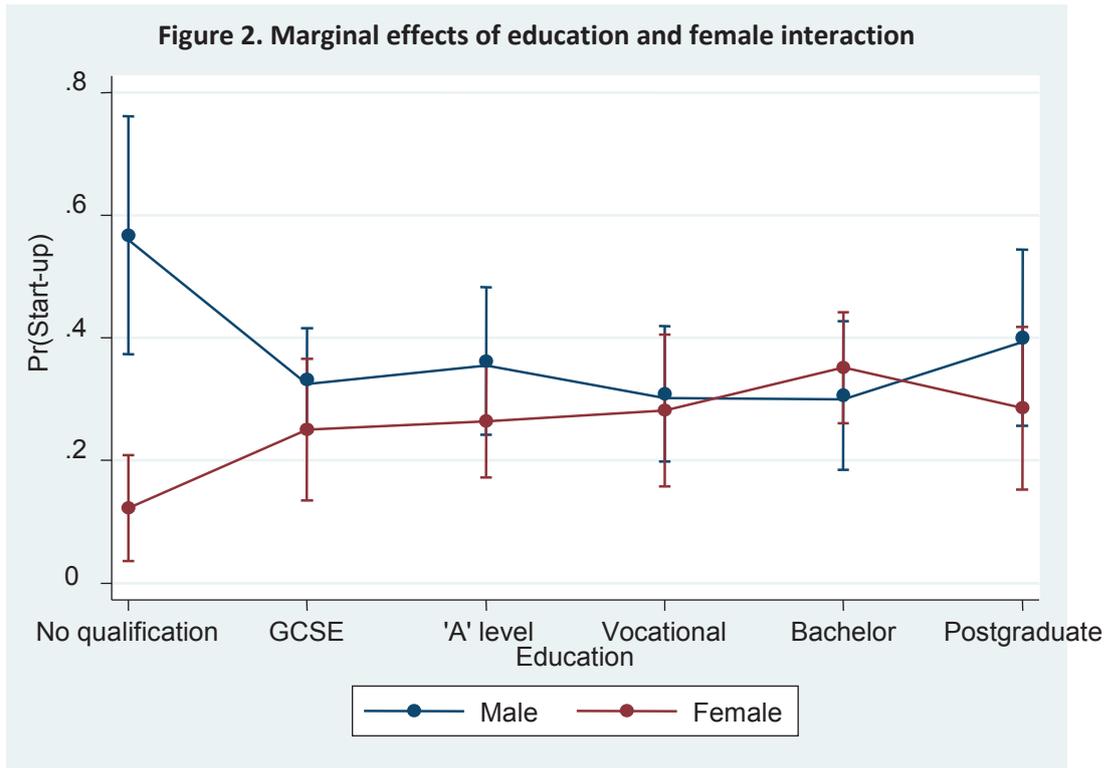
	Dependent variable : Start-up					
	(1)	(2)	(3)	(4)	(5)	(6)
Female		0.752*	0.154***	0.418	1.062	0.0114**
		(0.0960)	(0.0693)	(0.285)	(0.203)	(0.0195)
Wealth: Q2		1.406+	1.032		1.312	1.004
		(0.271)	(0.238)		(0.257)	(0.247)
Wealth: Q3		1.777**	1.133		1.680*	1.041
		(0.377)	(0.274)		(0.368)	(0.275)
Wealth: Q4		1.176	0.792		1.085	0.751
		(0.270)	(0.207)		(0.257)	(0.203)
Wealth: Q5		1.776*	0.900		1.699*	0.851
		(0.459)	(0.266)		(0.446)	(0.263)
GCSE		0.913		0.599+	0.894	0.516*
		(0.236)		(0.171)	(0.234)	(0.162)
'A' level		0.995		0.702	0.970	0.599+
		(0.230)		(0.189)	(0.227)	(0.177)
Vocational & others		0.918		0.624*	0.922	0.576*
		(0.180)		(0.144)	(0.184)	(0.144)
Bachelor		0.960		0.606+	0.985	0.510*
		(0.225)		(0.176)	(0.232)	(0.165)
Masters & doctorate		1.070		0.866	1.035	0.766
		(0.165)		(0.153)	(0.164)	(0.147)
Knowledge and skills		1.174	1.169	1.594	1.145	1.638
		(0.221)	(0.226)	(0.542)	(0.221)	(0.630)
In employment		0.612**	0.548***	0.674+	0.581**	0.599*
		(0.110)	(0.0971)	(0.154)	(0.110)	(0.140)
Knowing entrepreneurs: LSOA mean		0.724*	0.698*	0.740*	0.803	0.763+
		(0.0993)	(0.104)	(0.101)	(0.119)	(0.120)
Business owners: LSOA mean		1.327*	1.430*	1.248	1.678**	1.704**
		(0.167)	(0.199)	(0.176)	(0.289)	(0.327)
Age	1.045	1.157	1.126	1.222	1.130	1.148
	(0.278)	(0.333)	(0.338)	(0.350)	(0.331)	(0.368)
Knowing entrepreneurs	1.154+	1.361*	1.386*	1.325*	1.387*	1.439*
	(0.0995)	(0.172)	(0.182)	(0.162)	(0.180)	(0.207)
Business owners	0.678***	0.647***	0.635***	0.658***	0.643***	0.625***
	(0.0467)	(0.0513)	(0.0509)	(0.0522)	(0.0530)	(0.0537)
Fear of failure	0.866	0.765*	0.768*	0.749*	0.754*	0.723*

	(0.102)	(0.0938)	(0.100)	(0.0985)	(0.0931)	(0.103)
Good opportunities	1.419***	1.470***	1.495***	1.508***	1.470***	1.588***
	(0.131)	(0.151)	(0.151)	(0.155)	(0.151)	(0.179)
Business premises	1.171***	1.192***	1.229***	1.210***	1.188***	1.265***
	(0.0384)	(0.0460)	(0.0546)	(0.0500)	(0.0450)	(0.0647)
Urban areas	1.284	0.955	1.162	1.298	0.951	1.154
	(0.327)	(0.281)	(0.369)	(0.369)	(0.283)	(0.405)
Leicestershire	1.138	1.036	1.159	1.023	1.037	1.086
	(0.392)	(0.418)	(0.464)	(0.395)	(0.419)	(0.445)
Lincolnshire	0.635	0.577	0.627	0.635	0.566	0.645
	(0.273)	(0.284)	(0.299)	(0.307)	(0.279)	(0.330)
Northamptonshire	1.584	1.723	1.763	1.860	1.620	1.805
	(0.620)	(0.697)	(0.738)	(0.755)	(0.661)	(0.816)
Nottinghamshire	1.871+	1.896+	1.827	2.261*	1.810	1.790
	(0.642)	(0.737)	(0.727)	(0.816)	(0.702)	(0.745)
Wealth: Q2 * Female			2.448**			3.077**
			(0.770)			(1.097)
Wealth: Q3 * Female			3.177***			4.329***
			(1.073)			(1.676)
Wealth: Q4 * Female			2.692**			3.636**
			(1.017)			(1.569)
Wealth: Q5 * Female			5.719***			8.017***
			(2.238)			(3.524)
GCSE * Female				2.898*		3.082*
				(1.201)		(1.372)
'A' level * Female				2.443*		2.613**
				(0.848)		(0.974)
Vocational * Female				2.447**		2.390**
				(0.704)		(0.712)
Bachelor * Female				2.782**		3.780***
				(1.032)		(1.519)
Masters & doctorate * Female				1.649*		1.705*
				(0.350)		(0.398)
Knowledge & skills * Female				0.396		0.325
				(0.362)		(0.317)
In employment * Female				0.430		0.181*
				(0.353)		(0.157)
Share of knowing entrepreneurs * Female					0.170	0.0809*
					(0.207)	(0.102)
Share of business owners * Female					0.585*	0.597*
					(0.125)	(0.128)
Constant	0.291***	0.275*	0.240**	0.295*	0.353*	8.949*
	(0.108)	(0.139)	(0.125)	(0.177)	(0.181)	(9.988)
<i>Observations</i>	421	421	421	421	421	421
<i>Log Likelihood</i>	-213.3	-195.6	-185.5	-196.1	-191.8	-173.5
<i>Wald's chi-square</i>	78.11	90.67	95.89	81.30	94.48	98.25
<i>DF</i>	11	25	24	28	27	38
<i>Pseudo R--squared</i>	0.199	0.266	0.304	0.264	0.280	0.349
<i>Number of LSOA</i>	379	379	379	379	379	379

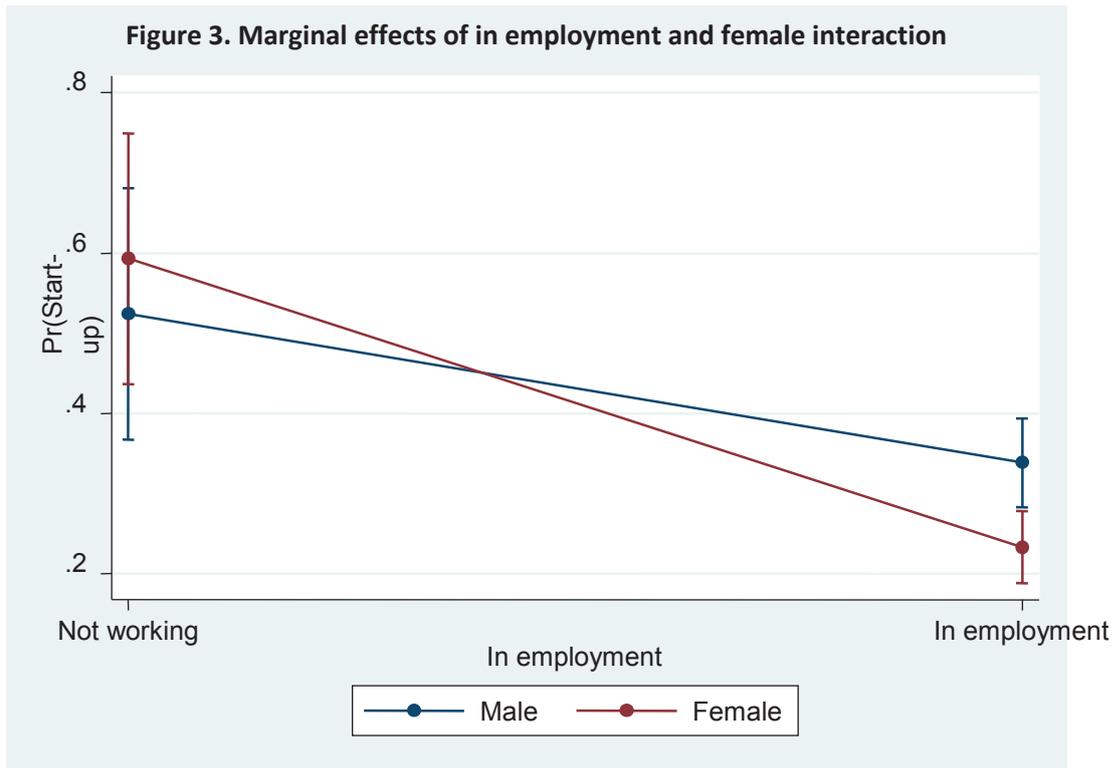
Notes: Fixed effects logit estimator.
 Exponentiated coefficients
 Robust standard errors in parentheses.
 Asterisks indicate significant level: where + p<0.1, * p<0.05, ** p<0.01, *** p<0.001



therefore, both effects are statistically significant; and the clear separation of the two CIs establishes that the difference between the male and female effects is statistically significant. However, the gap between the male and female propensity to start a business diminish steadily at higher levels of wealth (Q2), eventually disappearing (Q3, displaying no significant difference) and possibly, even being reversed at the highest level of wealth. Q5 increases the probability start-up by 34 percent for men and 46 percent for female entrepreneurs, even though in this case the greater female propensity is not significantly different from the male propensity at the conventional 5% level. Therefore, the result supports Hypothesis 1.

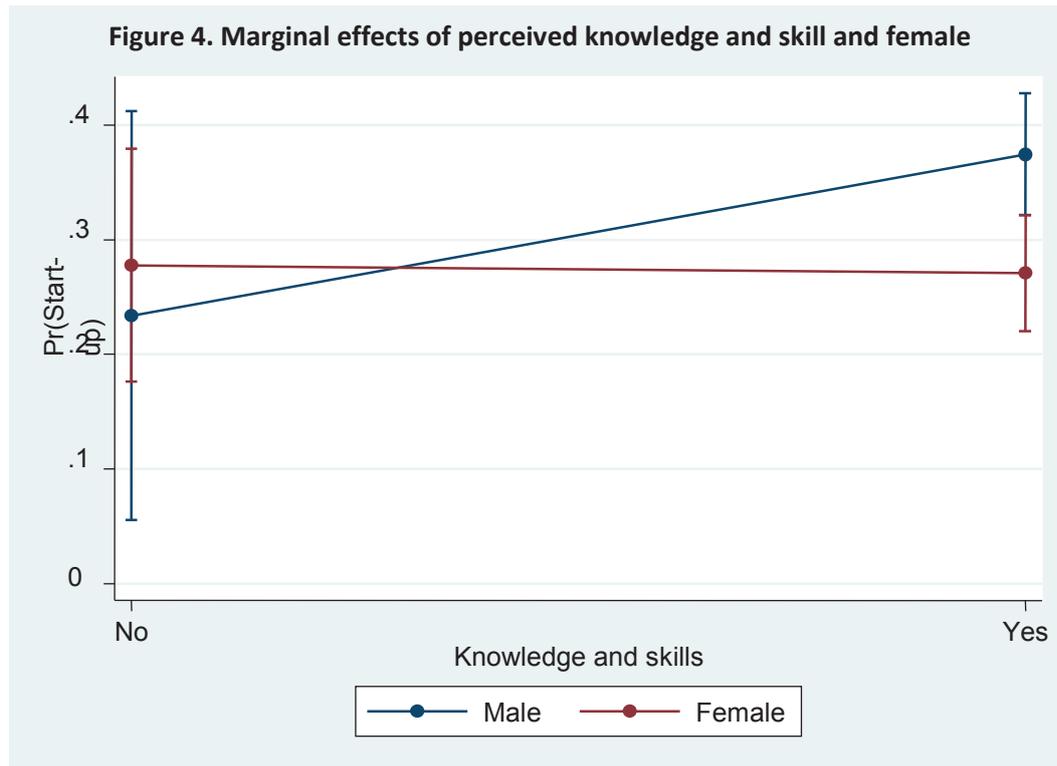


Hypothesis 2a posits that a female positively moderates the relationship between education and the probability of becoming an entrepreneur. In both Model 4 and Model 6, show that the coefficients of the interaction of higher levels of education and female are positive and statistically significant. Moreover Figure 2 show that at the lowest level of education (no formal qualification), female probability of engaging in starting a new business is around 12 percent while male probability is around 57 percent. The gap between the male and female propensity to start a business diminish quickly as we get to GSC level it eventually disappear, displaying a no significant difference and this effect is reversed at the bachelors degree level of education. However, the highest level – Postgraduate, increases the probability of start-up by 40 percent for male and 29 percent for female entrepreneurs, even though in this case the greater male propensity is not significantly different from the female propensity at the conventional 5 percent level. Therefore, the result supports Hypothesis 2a

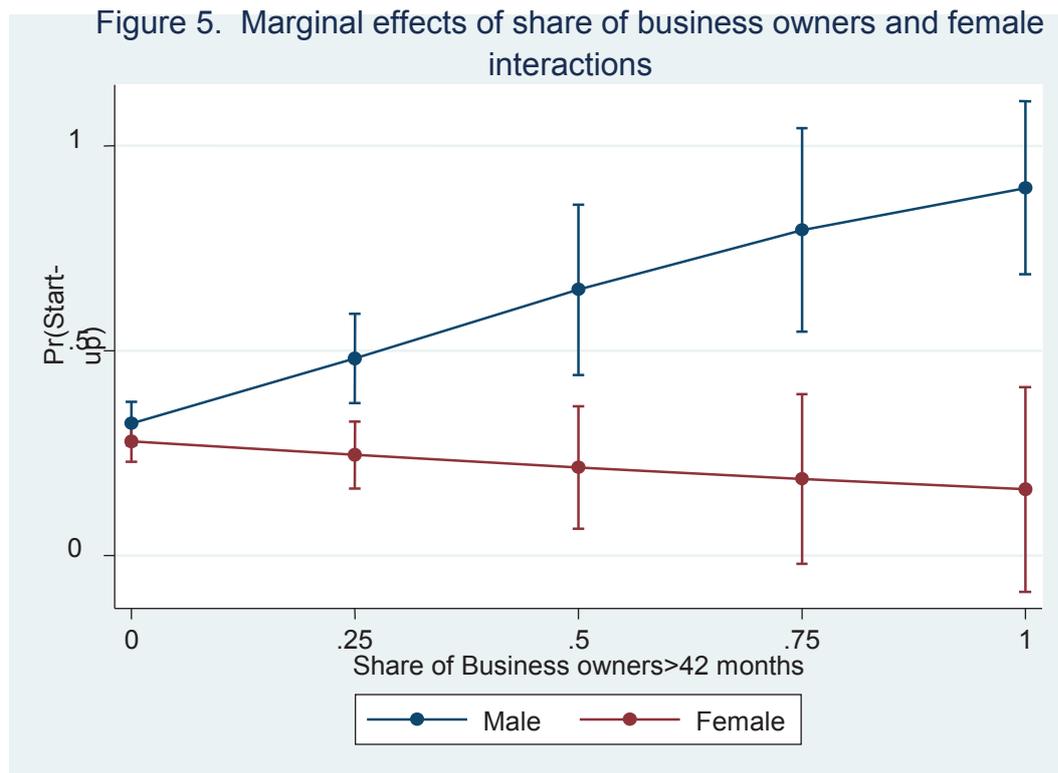


Hypothesis 2b posits gender positively moderates the relationship between in employment and the probability of becoming an entrepreneur and this relationship should be much stronger for male entrepreneurs. However, in Model 4, the coefficient for the interactions of work experience (In employment) with female is negative and is not statistically significant. But in Model 6 the interactions of work experience (In employment) with female turns out to be negative and statistically significant implying that the propensity to engage in start-up will be lower for females than the males. In line with this, Figure 3 show that being in employment increases the likelihood of starting a new firm by 34 percent for male and 23 percent for female. Here, we also see that there is a clear separation of the two CIs indicating that the difference between the male and female effects is statistically significant. Thus Hypothesis 2b is supported.

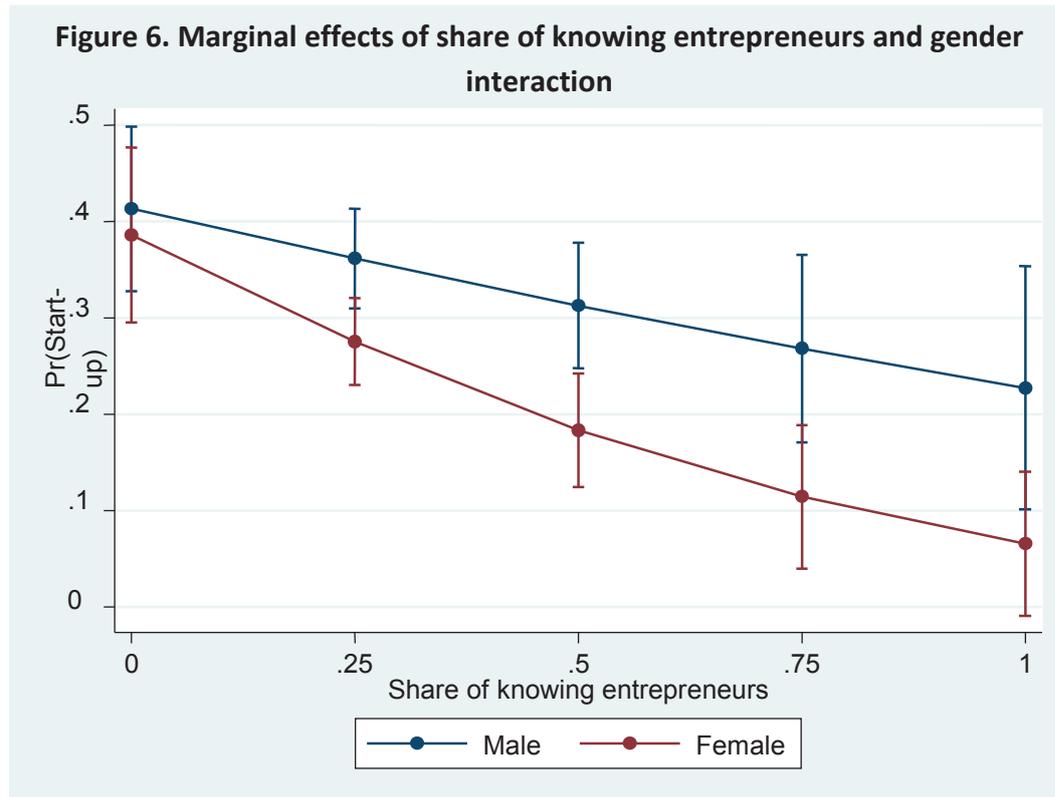
The argument proposed in Hypothesis 2c is that gender positively moderates the relationship between individuals with entrepreneurial specific knowledge and skills, and the probability of becoming an entrepreneur and this relationship should be much stronger for female entrepreneurs. However, the coefficient for the interaction of entrepreneurial specific knowledge and skills and female is not significant in both Model 4 and Model 6 but this does not mean that this variable is not important. Here, we also observe some movement on the effect of the gender variable (Female) which turns out to be negative and insignificant. A similar result is shown in Figure 4 which indicates that there is equality on male and female entry rate into entrepreneurial activity. Therefore we cannot officially confirm Hypothesis 2c.



Hypothesis 3a posits that gender positively moderates the relationship between the density of established owner-managers of businesses in the neighbourhood and the probability of becoming an entrepreneur and this positive relationship should be much stronger for male entrepreneurs. Indeed, Model 4 and 6 show that the coefficients of interactions between share of business owners in the neighbourhood with female is negative and significant. Consistent with our theoretical prediction Figure 5 shows that the magnitude of the interaction of share of business owners and female is much stronger for male than female. The gap between the male and female propensity to start a business widens as the share of business owners increases. At the highest level the probability of start-up increased from 26 to 96 percent for male and decreased from 13 to 4 percent for female entrepreneurs and in this case the greater male propensity is statistically significant at the conventional 5 percent level. Therefore, we can officially confirm H2a.



Hypothesis 3b argues that gender positively moderates the relationship between the density of individual who know successful entrepreneurs in the local neighbourhood and the probability of becoming an entrepreneur and this positive relationship should be much stronger for male entrepreneurs. Based on Model 5, the coefficient of the interaction of knowing other entrepreneurs with female is negative and is not statistically significant, but in Model 6 the coefficient becomes negative and statistically significant. However, Figure 6 shows that the magnitude of marginal effects of share of knowing entrepreneurs and female decreases for both male and female as the share of individuals who know other entrepreneurs in the neighbourhood increases. However, we could not confirm H3b: we did not find that gender positively moderates the relationship between the shares of knowing successful entrepreneurs in the local neighbourhood with male.



4.1 Limitations

This study has some limitations that might have influenced the results which should be addressed by future research. The GEM dataset does not contain information on personal income and wealth; therefore, an individual's address was used as a measure of wealth, which could imply measurement errors. We were unable to measure entrepreneurs' motivations directly. Male and female entrepreneurs might have different motivations for starting a business, for example, females are more likely to start a new business in order to achieve work-life balance [105]. Moreover, the GEM dataset does not include information that is relevant for understanding the financial bootstrapping strategies used by entrepreneurs which arguably little has been done to link bootstrapping RBT. We might have omitted some important variables such as those related to detailed representation of work experience that could be helpful in understanding how individual level resource affect the probability of entry into entrepreneurial activity. Here again, we cast doubt about the GEM measure of entrepreneurial specific skills, which is self reported and not based on objective information. Due to the cross sectional nature of the dataset, we have addressed the probability of engaging in entrepreneurial activity purely from a static point of view, and surely this is inferior to a dynamic analysis. Finally, another limitation we should bear in mind is that various types of resources are related. Specifically financial resources often correlate with human capital; therefore, the two effects may become confounded and attenuated. If that happens, there is potential attenuation bias: which could have worked against our tests.

5. Discussion and conclusion

This study sought to enhance our understanding of how the entrepreneurs' gender influences entry into entrepreneurship. We investigated how personal wealth, human capital and social capital affect the likelihood of starting a new business and how the relationship differs among female and male entrepreneurs. Prior studies that have examined start-ups have implicitly assumed the entrepreneurial occupation as homogenous despite the fact that small business owners are a diverse group. Likewise, previous studies considered entry as a homogenous outcome yet it is more difficult to enter some industries than the others. The novelty of this study is to investigate the impact of an individual's resource endowments on entry into entrepreneurial activity making a distinction between entry into self-employment and start-up (businesses that employ others). Herein, entry into self-employment may require small amount of financial capital and very little in terms of formal education. Yet when starting a business that employ others, entrepreneurs need to assemble substantial capital and the relevant skills required to successful operate. Moreover, the characteristics of potential entrepreneurs draw them toward certain types of new firms and discourage them from others. Consistent with this, our results provide evidence that financial and human capital is positively related to start-up and the relationship is stronger for female entrepreneurs than male entrepreneurs. In particular, we emphasize that educational levels predict entry into start-up activity but not in the manner suggested by the existing conventional wisdom. Higher levels of educational attainment strongly predict entre into start-up and lower levels of education predicts self-employment. Moreover skills possessed by highly educated people can be helpful in overcoming some of the entry barriers into business that employ others and less educated people may not be able to start a business in some sectors even if they want to.

Our results provide evidence that wealth is positively related to start-up and the relationship is stronger for female entrepreneurs than male entrepreneurs but the relationship is non-linear. Thus, across the five quintiles, financial constraints do not seem to be an obstacle to entry into start-up [42], [43], [58], [44].

Evidence suggest that entrepreneurial prior work experience and training in entrepreneurial specific skills plays an important role in developing self-confidence which may facilitate entry into entrepreneurial activity [106]. In line with this, it has been recognised that perceived knowledge and skills can be related to self-image, at the same time females may be less likely to perceive themselves as entrepreneurs resulting in lower confidence in relevant skills resulting in lower start-up rates. Given that work experience may be effective in developing perceived knowledge and skills and self confidence in female entrepreneurs what is needed is a deeper understanding of how women develop confidence about entrepreneurial capabilities [76]. In terms of public policy, policymakers need to develop programs that address female entrepreneurs' needs, in particular, focusing on developing skills, experiences relevant to entrepreneurship through activities that enhances their confidence. Likewise, women participation in economic activities has a strong effect on removing some barriers for women participation, empowering them to participate in all sectors of the economy including entrepreneurship. Policies that promote equal participation in the economy for women are may be effective in reducing the gender gap across different type of entrepreneurship.

References

- 1 H. Aldrich, *Organizations evolving*. 1999, London: Sage.
- 2 T. Beck, Demircuc-Kunt, A., and Levine, R., SMEs, growth, and poverty: Cross-country evidence. *Journal of Economic Growth*, 2005. **10**(3): p. 199-229.
- 3 M.A. Carree and Thurik, A.R., *Handbook of entrepreneurship research*. 2006, Cheltenham: Edward Elgar.
- 4 J. Blanden, Gregg, P., and Machin, S., Intergenerational mobility in europe and north america. *Report supported by the Sutton Trust, Centre for Economic Performance, London School of Economics*, 2005.
- 5 M. Minniti and Lévesque, M., Recent developments in the economics of entrepreneurship. *Journal of Business Venturing*, 2008. **23**(6): p. 603-612.
- 6 A. Atherton, Should government be stimulating start-ups? An assessment of the scope for public intervention in new venture formation. *Environment and Planning C: Government and Policy*, 2006. **24**(1): p. 21-36.
- 7 D.J. Storey, Entrepreneurship, small and medium sized enterprises and public policies, in *Handbook of entrepreneurship research*, Z. Acs and D. Audretsch, Editors. 2003, Kluwer Academic: Boston. p. 473-511.
- 8 J. Barney, Firm resources and sustained competitive advantage. *Journal of management*, 1991. **17**(1): p. 99-120.
- 9 J. Barney, Wright, M., and Ketchen Jr, D.J., The resource-based view of the firm: Ten years after 1991. *Journal of management*, 2001. **27**(6): p. 625-641.
- 10 M.A. Peteraf, The cornerstones of competitive advantage: a resource-based view. *Strategic Management Journal*, 1993. **14**(3): p. 179-191.
- 11 B. Wernerfelt, A resource-based view of the firm. *Strategic Management Journal*, 1984. **5**(2): p. 171-180.
- 12 R.A. Devine, et al., Female-led high-growth: Examining the role of human and financial resource management. *Journal of Small Business Management*, 2019. **57**(1): p. 81-109.
- 13 G. Wang, et al., CEO gender differences in careers and the moderating role of country culture: A meta-analytic investigation. *Organizational Behavior and Human Decision Processes*, 2018. **148**: p. 30-53.
- 14 A. Elam, et al., *Global Entrepreneurship Monitor (GEM) Women's Entrepreneurship 2020/21 Report: Thriving Through Crisis*. 2021, London,: he Global Entrepreneurship Research Association, London Business School. 2021.
- 15 M. Hart, et al., *Global Entrepreneurship Monitor: United Kingdom 2020 Monitoring Report*. 2021, Global Entrepreneurship Monitor Consortium: London
- 16 D. Cetindamar, et al., What the numbers tell: The impact of human, family and financial capital on women and men's entry into entrepreneurship in Turkey. *Entrepreneurship & Regional Development*, 2012. **24**(1-2): p. 29-51.
- 17 R.M. Sauer and Wiesemeyer, K.H., Entrepreneurship and gender: differential access to finance and divergent business value. *Oxford Review of Economic Policy*, 2018. **34**(4): p. 584-596.
- 18 R.M. Sauer and Wilson, T., The rise of female entrepreneurs: New evidence on gender differences in liquidity constraints. *European economic review*, 2016. **86**: p. 73-86.
- 19 E. Autio and Acs, Z., Intellectual property protection and the formation of entrepreneurial growth aspirations. *Strategic Entrepreneurship Journal*, 2010. **4**(3): p. 234-251.

- 20 S. Estrin, Korosteleva, J., and Mickiewicz, T., Which institutions encourage entrepreneurial growth aspirations? *Journal of Business Venturing*, 2013. **28**(4): p. 564-580.
- 21 D.B. Audretsch and Keilbach, M., Does entrepreneurship capital matter? *Entrepreneurship theory and practice*, 2004. **28**(5): p. 419-430.
- 22 D.B. Audretsch and Keilbach, M., Entrepreneurship capital and regional growth. *The Annals of Regional Science*, 2005. **39**(3): p. 457-469.
- 23 S.A. Alvarez and Busenitz, L.W., The entrepreneurship of resource-based theory. *Journal of management*, 2001. **27**(6): p. 755-775.
- 24 M.H. Anderson, Social networks and the cognitive motivation to realize network opportunities: A study of managers' information gathering behaviors. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior*, 2008. **29**(1): p. 51-78.
- 25 A.R. Anderson, Osseichuk, E., and Illingworth, L., Rural small businesses in turbulent times: impacts of the economic downturn. *The International Journal of Entrepreneurship and Innovation*, 2010. **11**(1): p. 45-56.
- 26 G. Bosworth and Gray, D., The role of the private sector in regional economic recovery: The case of a middling district in Middle England. *The International Journal of Entrepreneurship and Innovation*, 2012. **13**(3): p. 201-210.
- 27 C. Campos, et al., Impact of the Recession. *Regional Trends*, 2011. **43**(10/11): p. 1-69.
- 28 R. Ely and Padavic, I., A feminist analysis of organizational research on sex differences. *Academy of management review*, 2007. **32**(4): p. 1121-1143.
- 29 S.A. Alvarez and Barney, J., Discovery and creation: Alternative theories of entrepreneurial action. *Strategic Entrepreneurship Journal*, 2007. **1**(1□2): p. 11-26.
- 30 H. Bergmann and Stephan, U., Moving on from nascent entrepreneurship: Measuring cross-national differences in the transition to new business ownership. *Small Business Economics*, 2013. **41**(4): p. 945-959.
- 31 Y.Y. Kor, Mahoney, J.T., and Michael, S.C., Resources, capabilities and entrepreneurial perceptions. *Journal of Management Studies*, 2007. **44**(7): p. 1187-1212.
- 32 J. Chen and Hu, M., What types of homeowners are more likely to be entrepreneurs? The evidence from China. *Small Business Economics*, 2019. **52**(3): p. 633-649.
- 33 B. Gerhart and Feng, J., The resource-based view of the firm, human resources, and human capital: Progress and prospects. *Journal of management*, 2021: p. 0149206320978799.
- 34 I. Hameed, et al., A serial-mediation model to link entrepreneurship education and green entrepreneurial behavior: application of resource-based view and flow theory. *International journal of environmental research and public health*, 2021. **18**(2): p. 550.
- 35 D.B. Audretsch, Belitski, M., and Brush, C., Innovation in women-led firms: an empirical analysis. *Economics of Innovation and New Technology*, 2020: p. 1-21.
- 36 I. Dileo and Pereiro, T.G., Assessing the impact of individual and context factors on the entrepreneurial process. A cross-country multilevel approach. *International Entrepreneurship and Management Journal*, 2019. **15**(4): p. 1393-1441.
- 37 S. Sahasranamam, et al., Knowledge capital in social and commercial entrepreneurship: Investigating the role of informal institutions. *Journal of International Management*, 2021. **27**(1): p. 100833.
- 38 D.G. Blanchflower and Oswald, A.J., What makes an entrepreneur? *Journal of Labor Economics*, 1998. **16**(1): p. 26-60.

- 39 D.S. Evans and Jovanovic, B., An estimated model of entrepreneurial choice under liquidity constraints. *Journal of political economy*, 1989. **97**(4): p. 808-827.
- 40 D.S. Evans and Leighton, L.S., Some Empirical Aspects Of Entrepreneurship. *The American Economic Review*, 1989. **79**(3): p. 519.
- 41 J. Black, Meza, D.d., and Jeffreys, D., House prices, the supply of collateral and the enterprise economy. *The Economic Journal*, 1996. **106**(434): p. 60-75.
- 42 E. Hurst and Lusardi, A., Liquidity constraints, household wealth, and entrepreneurship. *Journal of political economy*, 2004. **112**(2): p. 319-347.
- 43 P.H. Kim, Aldrich, H.E., and Keister, L.A., Access (not) denied: The impact of financial, human, and cultural capital on entrepreneurial entry in the United States. *Small Business Economics*, 2006. **27**(1): p. 5-22.
- 44 K.B. Moore, *Do liquidity constraints matter for new entrepreneurs?* 2004, Board of Governors of the Federal Reserve System (US).
- 45 R.W. Fairlie and Krashinsky, H.A., Liquidity constraints, household wealth, and entrepreneurship revisited. *Review of Income and Wealth*, 2012.
- 46 S. Marlow and Carter, S., Accounting for change: professional status, gender disadvantage and self-employment. *Women in Management Review*, 2004.
- 47 J. Rouse and Jayawarna, D., The financing of disadvantaged entrepreneurs: are enterprise programmes overcoming the finance gap? *International Journal of Entrepreneurial Behavior & Research*, 2006.
- 48 K. Klyver, Nielsen, S.L., and Evald, M.R., Women's self-employment: An act of institutional (dis) integration? A multilevel, cross-country study. *Journal of Business Venturing*, 2013. **28**(4): p. 474-488.
- 49 Y. Pan and Sparks, J.R., Predictors, consequence, and measurement of ethical judgments: Review and meta-analysis. *Journal of business research*, 2012. **65**(1): p. 84-91.
- 50 I. Van Staveren, The Lehman sisters hypothesis. *Cambridge Journal of Economics*, 2014. **38**(5): p. 995-1014.
- 51 G.R. Franke, Crown, D.F., and Spake, D.F., Gender differences in ethical perceptions of business practices: a social role theory perspective. *Journal of applied psychology*, 1997. **82**(6): p. 920.
- 52 J.R. Graham, Harvey, C.R., and Huang, H., Investor competence, trading frequency, and home bias. *Management Science*, 2009. **55**(7): p. 1094-1106.
- 53 J.M. Unger, et al., Human capital and entrepreneurial success: A meta-analytical review. *Journal of Business Venturing*, 2011. **26**(3): p. 341-358.
- 54 J. Van der Sluis, Van Praag, M., and Vijverberg, W., Education and entrepreneurship selection and performance: A review of the empirical literature. *Journal of Economic Surveys*, 2008. **22**(5): p. 795-841.
- 55 S. Estrin, Mickiewicz, T., and Stephan, U., Human capital in social and commercial entrepreneurship. *Journal of Business Venturing*, 2016. **31**(4): p. 449-467.
- 56 T. Mickiewicz, et al., Resource endowment and opportunity cost effects along the stages of entrepreneurship. *Small Business Economics*, 2017. **48**(4): p. 953-976.
- 57 J.M. Millan, et al., The value of an educated population for an individual's entrepreneurship success. *Journal of Business Venturing*, 2014. **29**(5): p. 612-632.
- 58 K. Klyver and Schenkel, M.T., From resource access to use: Exploring the impact of resource combinations on nascent entrepreneurship. *Journal of Small Business Management*, 2013. **51**(4): p. 539-556.
- 59 A.C. Cooper, Gimeno-Gascon, F.J., and Woo, C.Y., Initial human and financial capital as predictors of new venture performance. *Journal of Business Venturing*, 1994. **9**(5): p. 371-395.

- 60 C. Brush, et al., The influence of human capital factors and context on women's entrepreneurship: Which matters more? *Journal of Business Venturing Insights*, 2017. **8**: p. 105-113.
- 61 D. Ucbasaran, et al., The nature of entrepreneurial experience, business failure and comparative optimism. *Journal of Business Venturing*, 2010. **25**(6): p. 541-555.
- 62 M. Frese, et al., Business owners' action planning and its relationship to business success in three African countries. *Journal of applied psychology*, 2007. **92**(6): p. 1481.
- 63 S. Shane, Locke, E.A., and Collins, C.J., Entrepreneurial motivation. *Human resource management review*, 2003. **13**(2): p. 257-279.
- 64 P. Westhead, Ucbasaran, D., and Wright, M., Decisions, actions, and performance: do novice, serial, and portfolio entrepreneurs differ? *Journal of Small Business Management*, 2005. **43**(4): p. 393-417.
- 65 G. Bruton, et al., *New financial alternatives in seeding entrepreneurship: Microfinance, crowdfunding, and peer-to-peer innovations*. 2015, SAGE Publications Sage CA: Los Angeles, CA. p. 9-26.
- 66 S.C. Parker, *The economics of entrepreneurship*. 2018, Cambridge: Cambridge University Press.
- 67 D.J. Storey, *Understanding the small business sector*. 2016, London: Routledge.
- 68 G.S. Becker, *Human capital: A theoretical and empirical analysis, with special reference to education*. 1964, New York: University of Chicago Press.
- 69 G. Cassar, Entrepreneur opportunity costs and intended venture growth. *Journal of Business Venturing*, 2006. **21**(5): p. 610-632.
- 70 P. Arenius and Minniti, M., Perceptual variables and nascent entrepreneurship. *Small Business Economics*, 2005. **24**(3): p. 233-247.
- 71 A. Bandura, Reflections on self-efficacy. *Advances in behaviour research and therapy*, 1978. **1**(4): p. 237-269.
- 72 D. De Clercq and Arenius, P., The role of knowledge in business start-up activity. *International Small Business Journal*, 2006. **24**(4): p. 339-358.
- 73 A.C. Corbett, Learning asymmetries and the discovery of entrepreneurial opportunities. *Journal of Business Venturing*, 2007. **22**(1): p. 97-118.
- 74 P.G. Greene, et al., *Women entrepreneurs: Moving front and center: An overview of research and theory*. 2003, Coleman White Paper, Coleman Foundation. p. 1-47.
- 75 S. Chowdhury and Endres, M. Gender difference and the formation of entrepreneurial self-efficacy. in *United States Association of Small Business (USASBE) Annual Conference, Indian Wells, CA*. 2005: Citeseer.
- 76 F. Wilson, Kickul, J., and Marlino, D., Gender, entrepreneurial self-efficacy, and entrepreneurial career intentions: Implications for entrepreneurship education. *Entrepreneurship theory and practice*, 2007. **31**(3): p. 387-406.
- 77 E.H. Buttner, Examining female entrepreneurs' management style: An application of a relational frame. *Journal of business ethics*, 2001. **29**(3): p. 253-269.
- 78 V. Bamiatzi, et al., The Role of Competencies in Shaping the Leadership Style of Female Entrepreneurs: The Case of North West of England, Yorkshire, and North Wales. *Journal of Small Business Management*, 2015. **53**(3): p. 627-644.
- 79 P.P. Fu, et al., Pursuit of whose happiness? Executive leaders' transformational behaviors and personal values. *Administrative science quarterly*, 2010. **55**(2): p. 222-254.
- 80 X.-a. Zhang, et al., Getting everyone on board: The effect of differentiated transformational leadership by CEOs on top management team effectiveness and leader-rated firm performance. *Journal of management*, 2015. **41**(7): p. 1898-1933.

- 81 H. Hoang and Antoncic, B., Network-based research in entrepreneurship: A critical review. *Journal of Business Venturing*, 2003. **18**(2): p. 165-187.
- 82 M.S. Granovetter, The strength of weak ties. *American journal of sociology*, 1973. **78**(6): p. 1360-1380.
- 83 J.S. Coleman, Social capital in the creation of human capital. *American journal of sociology*, 1988. **94**: p. S95-S120.
- 84 J. Son and Lin, N., Social capital and civic action: A network-based approach. *Social Science Research*, 2008. **37**(1): p. 330-349.
- 85 M. Hughes, Ireland, R.D., and Morgan, R.E., Stimulating dynamic value: Social capital and business incubation as a pathway to competitive success. *Long Range Planning*, 2007. **40**(2): p. 154-177.
- 86 N. Carter, et al., Women entrepreneurs who break through to equity financing: the influence of human, social and financial capital. *Venture Capital: an international journal of entrepreneurial finance*, 2003. **5**(1): p. 1-28.
- 87 P. Davidsson and Honig, B., The role of social and human capital among nascent entrepreneurs. *Journal of Business Venturing*, 2003. **18**(3): p. 301-331.
- 88 M. McPherson, Smith-Lovin, L., and Cook, J.M., Birds of a feather: Homophily in social networks. *Annual review of sociology*, 2001. **27**(1): p. 415-444.
- 89 P. McGowan and Hampton, A., An exploration of networking practices of female entrepreneurs, in *Female Entrepreneurship*. 2006, Routledge: New York. p. 126-150.
- 90 N. Bosma, et al., GEM Manual: A report on the design, data and quality control of the Global Entrepreneurship Monitor. *Global Entrepreneurship Monitor*, 2012.
- 91 J.S. Frankish, et al., Is entrepreneurship a route out of deprivation? *Regional studies*, 2014. **48**(6): p. 1090-1107.
- 92 J.P. Harding and Rosenthal, S.S., Homeownership, housing capital gains and self-employment. *Journal of urban economics*, 2017. **99**: p. 120-135.
- 93 E. Hurst and Pugsley, B.W., Wealth, Tastes, and Entrepreneurial Choice, in *Measuring Entrepreneurial Businesses: Current Knowledge and Challenges*, J. Haltiwanger, et al., Editors. 2017, University of Chicago Press: NY. p. 111-152.
- 94 S. Liu and Zhang, S., Housing wealth changes and entrepreneurship: Evidence from urban China. *China Economic Review*, 2021. **69**: p. 101656.
- 95 DCLG, *The Indices of Multiple Deprivation 2007*. 2010, London: DCLG.
- 96 S. Estrin and Mickiewicz, T., Institutions and female entrepreneurship. *Small Business Economics*, 2011. **37**(4): p. 397.
- 97 N. Simões, Crespo, N., and Moreira, S., Individual determinants of self-employment entry: What do we really know? *Journal of Economic Surveys*, 2016. **30**(4): p. 783-806.
- 98 F. Bastié, Cieply, S., and Cussy, P., The entrepreneur's mode of entry: the effect of social and financial capital. *Small Business Economics*, 2013. **40**(4): p. 865-877.
- 99 C. Kalantaridis and Bika, Z., In-migrant entrepreneurship in rural England: beyond local embeddedness. *Entrepreneurship and Regional Development*, 2006. **18**(2): p. 109-131.
- 100 T. Mickiewicz, et al., Ethnic pluralism, immigration and entrepreneurship. *Regional studies*, 2019. **53**(1): p. 80-94.
- 101 F.W. Nyakudya, Positive local externalities of immigration on entrepreneurship: Evidence from the UK East Midlands region. *Local Economy*, 2019. **34**(3): p. 271-293.
- 102 R. Lee, et al., Investigating the social capital and resource acquisition of entrepreneurs residing in deprived areas of England. *Environment and Planning C: Government and Policy*, 2011. **29**(6): p. 1054-1072.

- 103 W.H. Greene and Hensher, D.A., *Modeling Ordered Choices: A Primer* 2010, Cambridge: Cambridge University Press.
- 104 J. Cohen, et al., *Applied multiple correlation/regression analysis for the behavioral sciences*. 2003, Mahwah, NJ: Lawrence Erlbaum Associates.
- 105 A.E. Davis and Shaver, K.G., Understanding gendered variations in business growth intentions across the life course. *Entrepreneurship theory and practice*, 2012. **36**(3): p. 495-512.
- 106 B. Rotefoss and Kolvereid, L., Aspiring, nascent and fledgling entrepreneurs: an investigation of the business start-up process. *Entrepreneurship & Regional Development*, 2005. **17**(2): p. 109-127.

The Influence of Institutional Environment on the Entrepreneurial Performance in Egypt: The Mediating Role of Innovation Capacity

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Abstract— Entrepreneurial activities have been globally acknowledged as the key dynamic factors that foster the countries' progress and development. In the contemporary world, entrepreneurs dedicate their time and effort to hunt new opportunities primarily directed toward the high levels of innovation. Consequently, entrepreneurial firms can have a competitive and dominating position in the market by capitalising on their innovation capacities to develop new innovative products. Hence, this study aims to investigate the institutional environment as an influential context that has a holistic effect in relevance to the innovation capacity. The prominent subfactors of innovation capacity such as resources exploitation, marketing, manufacturing, and management capacities will be observed within the innovation process. Additionally, the impact of the innovation capacity as a significant factor on boosting the entrepreneurial performance will be critically hypothesized and examined in the study. Accordingly, such study assesses the extent to which the dimensions of the innovation capacity of the entrepreneurial firms play a dominant role as a moderating variable in the correlation between institutional environment and entrepreneurial performance. The examination of such correlation is based on the institutional theory introduced by Scott (1995) and North (1991). Hence, the study adopts a mixed-method approach to present a comprehensive and multidimensional empirical analysis of data collected from entrepreneurial firms in Egypt, specifically Cairo.

Keywords— institutional environment, entrepreneurship, innovation capacity, entrepreneurial performance, Egypt.

Grand Paris Residential Real Estate as an Effective Hedge Against Inflation

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Abstract

Following a long inflationary period from the post-war era to the mid-1980s (+10.1% annually), France went through a moderate inflation period between 1986 and 2001 (+2.1% annually), and even lower inflation between 2002 and 2016 (+1.4% annually). In 2022, inflation in France increased rapidly and reached 4.5% over one year in March, according to INSEE estimates. Over a long period, even low inflation has an impact on portfolio value and households' purchasing power. In such a context, inflation hedging should remain an important issue for investors. In particular, long-term investors, who are concerned with the protection of their wealth, seek to hold effective hedging assets.

Considering a mixed-asset portfolio composed by housing assets (residential real estate in 150 Grand Paris communes) as well as financial assets, and using both correlation and regression analysis, results confirm the attribute of the direct housing investment as inflation hedge, especially particularly against its unexpected component. Further, cash and bonds were found to provide respectively a partial and an over hedge against unexpected inflation. Stocks act as a perverse hedge against unexpected inflation and provides no significant positive hedge against expected inflation.

Keywords: Direct housing, inflation, hedging ability, optimal portfolio, "Grand Paris" metropolis

Disentangling Reliability from Relevance in Value-Relevance Tests

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ABSTRACT

Vast literature investigates value-relevance using the relation between stock returns and earnings. However, "value-relevance tests generally are joint tests of relevance and reliability" (Barth, Beaver, & Landsman, 2001). This study extends the standard test and addresses the FASB's call to disentangle reliability apart from relevance (SFAC 8, BC3.30, 2010). We use the extended test to examine firm categories along two dimensions: profits versus losses and intensive versus scarce use of accounting estimates. Results show that reliability and relevance are complements when both are sufficiently high, but reliability has no significant impact on the usefulness of earnings when relevance is weak.

Keywords: Reliability, relevance, value-relevance, losses, accounting estimates.
JEL classification: M41; G14.

Disentangling Reliability from Relevance in Value-Relevance Tests

1. Introduction

Relevance and reliability are the basic premise of useful accounting information. Statement of Financial Accounting Concepts No. 8 (2010) defined accounting information as reliable (termed "faithfully represented")¹ if it is complete, neutral and free from error and challenged the value-relevance stream of studies in empirical accounting research: "*studies have not yet provided techniques for empirically measuring faithful representation apart from relevance*" (SFAC 8, BC3.30). Although numerous studies examined value-relevance using the relationship between stock returns and earnings (Kothari, 2001), Barth, Beaver, and Landsman (2001, p. 81) state: "*Value-relevance tests generally are joint tests of relevance and reliability.*" That is, a significant earnings-response-coefficient, ERC, suggests the accounting variable is both relevant and reliable to some degree. Addressing the FASB call, the objective of this study is to disentangle reliability from relevance in standard value-relevance tests.

Operationalizing measurement of reliability, we follow prior studies for constructing a comprehensive measure. Specifically, we build on observable incidents formerly associated in the literature with lack of completeness, bias, or

¹ SFAC 8 uses the term "faithful representation" instead of "reliability". In this study, we use the terms reliability and faithful representation interchangeably. We note that substance over form, prudence (conservatism), and verifiability, which were aspects of reliability in SFAC 2, are not considered aspects of faithful representation in SFAC 8 (see section BC3.19).

erroneous accounting information, as directed by SFAC 8. We utilize the reliability measure to extend the standard value-relevance tests for gaining insights into reliability and relevance as characteristics of useful accounting information. Particularly, we look for cases where increasing reliability or relevance does not improve the usefulness of reported earnings.

We start by disentangling reliability from relevance in estimating the usefulness of losses versus profits, where about 30% of our sample firms report losses. Hayn (1995) and Collins, Pincus, and Xie (1999) report that the value-relevance of losses is significantly lower than the value-relevance of profits. Yet, it remains unclear whether usefulness of reported losses is weak due to low reliability or low relevance (or both). Utilizing the proposed reliability measure, we find that, on average, losses are significantly less reliable than profits. We then utilize the extended tests for further testing the incremental usefulness of profits over losses controlled for reliability level. For high reliability reports, the estimated ERC for losses is significantly lower than the respective ERC estimated for profits. A significantly greater ERC for profits over losses is also estimated using low reliability reports. Controlling for reliability levels, we interpret the results as suggesting that the relevance of losses is significantly lower than the relevance of profits. However, we find that the ERC estimated for high reliability loss reports is insignificantly different from the ERC estimated for low reliability loss reports. We conclude that high reliability in loss firms does not enhance the usefulness of reported earnings because it does not compensate for weak relevance. The results are robust to alternative specifications and robustness checks.

Next, we conduct similar analysis based on the intensity of reporting accounting estimates. We utilize 11 accounting estimates based on the list in Lev, Li, and Sougiannis (2010) and test the relevance and reliability of firms whose financial statements include numerous estimates versus firms that sparsely use estimates. Utilizing the proposed reliability measure, we find that reporting more accounting estimates is negatively and significantly associated with reliability. Extending the value-relevance tests for profit reports with high intensity of accounting estimates, the estimated ERC for high reliability reports is significantly greater than the estimated ERC for low reliability reports. As expected for firms with high intensity of accounting estimates, this result suggests that more reliable reports improve their usefulness. Second, we look at the group of profit reports with just a few accounting estimates. In this group, the estimated ERC for highly reliable reports is insignificantly different from the estimated ERC for low reliability reports. We interpret the findings as suggesting that reliability does not enhance the usefulness of reported profits in firms with insufficient relevance due to rare reliance on accounting estimates. Again, we conclude that high reliability in such firms does not enhance the usefulness of reported earnings due to weak relevance.

The contribution lies in addressing the FASB's call to disentangle reliability from relevance in value-relevance tests, which, in turn, allows for empirically testing a meaningful presumption assumed by standard-setters. The standard-setter assumes *"information must be both relevant and faithfully represented if it is to be useful. Neither a faithful representation of an irrelevant phenomenon, nor an unfaithful representation of a relevant phenomenon, helps users make good decisions."* (SFAC 8, QC17). The findings in both settings we use suggest that increasing reliability does not improve the usefulness of the reports in the presence of insufficient relevance, which is consistent with QC17. Overall, this study confirms QC17 by demonstrating frequent cases where increasing reliability does

not improve the usefulness of reported earnings due to insufficient relevance. Our results extends findings in Kadous, Koonce and Thayer (2012), who use experiment setting to explore inter-dependencies between relevance and reliability, and infer that relevance and reliability are not independent.

The remainder of the study proceeds as follows: Section 2 discusses the conceptual framework and standard value-relevance tests. Section 3 describes research design. Section 4 disentangles reliability from relevance in loss versus profit firms and Sections 5 explores the impact of accounting estimates on the usefulness of accounting earnings. Section 6 summarizes.

2. Relevance and reliability in standard value-relevance tests

2.1 The conceptual framework

The FASB's goal in setting standards is to heighten the usefulness to users of financial statements of the information that entities report in financial statements. In assessing whether the usefulness of information would be enhanced, the FASB considers relevance and reliability as two qualitative characteristics that make useful accounting information. Both characteristics are a quality emphasized in every accounting framework. Chapter 3 of the FASB's Statement of Financial Accounting Concepts No. 8, (2010), *Qualitative Characteristics of Useful Financial Information*, defines these characteristics. Relevant financial information is capable of making a difference in the decisions made by users (QC6). The term 'reliability' was replaced by 'faithful representation'. To be a perfectly faithful representation, a depiction is faithfully represented if the representation is *complete, neutral, and free from error* (QC12).

Information must be both relevant and reliable if it is to be useful. Neither a reliability of an irrelevant economic construct nor unreliable information about a relevant economic construct helps users make decisions (QC17). Particularly, SFAC 8 (2010, QC16) states that reliability, by itself, does not necessarily result in useful information. In similar vein, a relevant economic construct, by itself, does not necessarily result in useful information. Accordingly, measuring the effects of relevance and reliability on the usefulness of accounting information is key issue for accounting regulators. Particularly, this study is an attempt to unravel the joint measurement of the relevance and reliability of earnings reported in financial statements.

2.2 Standard value-relevance tests

The value-relevance stream of studies attempts to operationalize key aspects of the FASB's conceptual framework to assess the usefulness of reported earnings and additional accounting variables. Value-relevance studies use share prices (and/or stock returns) to infer whether capital market participants consider accounting information to be sufficiently relevant and reliable to be useful in making investment decisions. This stream of studies implicitly assume: (1) investors perceive the relevance of a specific piece of accounting information for the future cash flows of the firm, (2) investors perceive the reliability of that specific piece of accounting information, (3) an asset-pricing model that the

investors use to control for all the other factors that explain share prices, such as risk, and (4) market efficiency. Because the standard value-relevance tests are joint tests, they allow drawing inferences about reliability and relevance together, but not separately (Maine and Wahlen, 2006). Barth, Beaver, and Landsman (2001, p. 81) make a clear argument:

"Value-relevance tests generally are joint tests of relevance and reliability. Although finding value-relevance indicates the accounting amount is relevant and reliable, at least to some degree, it is difficult to attribute the cause of lack of value-relevance to one or the other attribute. Neither relevance nor reliability is a dichotomous attribute, and SFAC No. 5 does not specify "how much" relevance or reliability is sufficient to meet the FASB's criteria. In addition, it is difficult to test separately relevance and reliability of an accounting amount".

In similar vein, SFAC 8 draws attention to the measurement of reliability and relevance. Criticizing the empirical accounting research, SFAC 8 (2010, BC3.30) emphasizes that

"Empirical accounting researchers have accumulated considerable evidence supporting relevant and faithfully represented financial information through correlation with changes in the market prices of entities' equity or debt instruments. However, such studies have not provided techniques for empirically measuring faithful representation apart from relevance."

We address this void by disentangling reliability apart from relevance. To do that, we build on prior studies to propose a measure of reliability and extend the standard value-relevance tests.

3. Research design

3.1 Measuring reliability

We build on prior studies for measuring reliability of reported earnings in consistence with the definition in the conceptual framework. To facilitate a separation between relevance and reliability of reported earnings in standard value-relevance tests, we construct a reliability measure based on prior literature that acknowledges five observable indicators suggesting impaired completeness, lack of neutrality, and errors in reported earnings (SFAC 8, 2010, QC12).^{2,3}

² Richardson, Sloan, Soliman, and Tuna (2005) and Bandyopadhyay, Chen, Huang, and Jha (2009) define reliability as earnings' ability to predict one-year-ahead earnings. Lev, Li, and Sougiannis (2010) define reliability as earnings' ability to predict one-year-ahead cash flows. This approach is inconsistent with the definition of reliability within the conceptual framework (Riedl, 2010).

³ Some prior reliability studies employ item-specific metrics tailored to the research question tested in each study (Dietrich, Harris, and Muller 2001; Cotter and Richardson 2002; Kallapur and Kwan 2004; Barth, Landsman, and Rendleman 1998). None of these measures lends itself for an examination of reliability of reported earnings in a value-relevance context, as the research design in each of the studies relates to a particular setting.

The first indicator is the issuing of restatements, revealing that earnings reported on prior periods did not reliably reflect the firm's underlying economic constructs and need to be restated. The second indicator is internal controls demonstrating one or more material weaknesses and consequent non-compliance with the Public Company Accounting Oversight Board (PCAOB) Auditing Standard No. 5 (2007) requirement for effective internal control over financial reporting. Moreover, such weaknesses is likely to suggest that a material misstatement of the company's reported earnings may not be prevented or detected on a timely basis. Accordingly, ineffective controls disclosed under the Sarbanes-Oxley Act (SOX) suggest impaired reliability (see also Ashbaugh-Skaife, Collins, and Kinney 2007; Ogneva, Subramanyam, and Raghunandan 2007; Schneider and Church 2008; Clinton, Pinello and Skaife 2014). The third indicator is just meeting/beating earnings benchmarks. Prior literature hypothesizes and finds that firms that slightly beat benchmarks are more likely to have managed earnings (see Roychowdhury 2006; Cohen, Dey, and Lys 2008; Jiang 2008; Cohen, Darrough, Huang, and Zach 2011; Zang 2012).⁴ That is, just meeting/beating earnings benchmarks is likely to reflect biased accounting figures. Fourth, prior studies suggest that a change of auditor increases the likelihood of mis-stated earnings. Stice (1991) notes that a new auditor is less able to detect material misstatements in his audit process because he lacks familiarity with the client. Hence, the risk of audit failure and subsequent litigation is higher during an initial engagement than in subsequent years (see also Johnson, Khurana, and Reynolds 2002; Chung and Kallapur 2003; Myers, Myers and Omer 2003; Stanley and Dezoort 2007). The fifth indicator is a qualified, disclaimed, or adverse audit opinion. The auditor's failure or reluctance to produce an unqualified opinion indicates a reporting problem (Lev and Thiagarajan 1993; Butler, Leone, and Willenborg 2004). Admittedly, qualified, disclaimed, and adverse audit opinions are rare. Nevertheless, we include this indicator in the reliability measure for completeness of reported earnings.

We assume the reliability of reported earnings is adversely affected by the five indicators comprising the metric. Accordingly, we propose a comprehensive reliability measure, RSCORE, which aims to capture the extent to which financial statements contain accounting information that is complete, neutral, and free from error. RSCORE is based on the five adverse reliability indicators detailed above, and counts for each firm-year the number of indicators known before financial statements are announced and recorded out of the following:

- I. Filing of a restatement (RESTATE) – RSCORE builds on information known to investors. Thus, we record whether a restatement of earlier financial statements was filed during the year prior to the announcement of financial statements.
- II. Material weakness in internal controls over financial reporting (MW),

⁴ The empirical work in this stream of literature typically detects earnings management using discretionary accruals (e.g., Subramanyam 1996; Francis, Lafond, Olsson, and Schipper 2005). However, accrual metrics do not lend themselves to measuring reliability apart from relevance because accruals influence both the reliability and relevance of accounting information. Also, weak reliability is not always due to earnings management. Sometimes it stem from an unintentional error or incomplete information.

- disclosed either under Section 302 or under Section 404 of SOX.
- III. Just meeting/beating earnings benchmarks (MBE) – We employ the three earnings benchmarks frequently used in the literature: zero, last-year's earnings per share (EPS), and analyst forecast consensus (Roychowdhury 2006; Cohen, Dey and Lys 2008; Jiang 2008; Cohen, Darrough, Huang, and Zach 2011; Zang 2012). We use these three benchmarks alternatively; that is, meeting or slightly beating either of them indicates manipulation, and hence impaired reliability.⁵
 - IV. Change of auditor (CHANGE).
 - V. Auditor adverse, qualified, or no opinion (OPINION).

Specifically, for every firm-year, RSCORE counts the number of adverse indicators recorded out of the five indicators listed above with a **negative sign**. That is, highest reliability is indicated by RSCORE=0 (none of the indicators exist), whereas RSCORE=-5 indicates lowest reliability (all five indicators exist).

RSCORE is an appealing measure of reliability for a number of reasons: (i) it captures the indicators of reliability of reported earnings, which are complete, neutral, and free from error, as documented in the literature and stated in SFAC 8; (ii) it is a observable, transparent, and easily reproducible metric; (iii) it does not involve relevance; and (iv) it is an equal weight procedure that follows Lev and Thiagarajan (1993), Piotroski (2000), and Gompers, Ishii, and Metrick (2003). It is a simple procedure that avoids complex and controversial weighting of the relative impact of different indices.⁶

Keeping in mind our objective to disentangle between reliability and relevance, we note that prior studies report a significant relationship between some of the components of RSCORE (on a stand-alone basis) and ERCs.⁷ However, these studies document a relationship without disentangling between reliability and relevance. Utilizing RSCORE provides means for comparing the differential usefulness of reported earnings in a setting of reliable information (RSCORE=0) with that in a setting of weak reliability (RSCORE<0). Taken as a whole, using RSCORE provides means to extend the standard value-relevance tests.

⁵ Following Cohen, Dey, and Lys (2008) and Zang (2012), observations suspected of indicating just beating/meeting the zero benchmark are defined as firm-years with earnings before extraordinary items over lagged assets between 0 and 0.005. Observations suspected of indicating just beating/meeting last-year's earnings are firm-years with a change in basic EPS excluding extraordinary items from last year between zero and two cents; and observations suspected of indicating just beating/meeting the analyst forecast consensus are firm-years with an actual EPS less the analyst forecast consensus outstanding prior to the earnings announcement date between zero and one cent.

⁶ We replicated the analyses with alternative weights for the RSCORE components (ignoring OPINION and according equal weights to the remaining four indicators and frequency-weights). The results remain essentially the same.

⁷ For instance, Wilson (2008) documents a decline in value-relevance of accounting information following restatements, Chen, Krishna, Sami and Zhou (2013) use ERCs to show that clean internal control reports are a sign of increased credibility of earnings, Singer and You (2011) show the effect of disclosures of material weaknesses on earnings quality, Choi and Jeter (1992) report a relationship between audit opinions and ERCs, and Hackenbrack and Hogan (2002) report market response to various reasons for auditor change.

3.2. Sample and descriptive statistics

We downloaded data on all non-financial firms on Compustat from 2002 until 2012 with available total assets and market value data, a total of 57,169 firm-years. Our sample period begins in 2002 because this year is the earliest for which we were able to obtain data on material weaknesses over internal controls reported under SOX. We deleted observations with share prices below one dollar from the sample to eliminate economically marginal firms. We also required firms to have at least two consecutive years of available data in order to allow for deflation of variables and for sufficient CRSP stock return data. We did not limit the applicability of RSCORE to observations with available I/B/E/S data. Thus, when I/B/E/S data were unavailable, we utilized earnings per share or change in earnings per share. These requirements reduced the sample size to 40,542 firm-year observations.

To compute RSCORE, we utilized data on its five components. We extracted restatements from the AuditAnalytics database, where each restatement is attributed to the year in which the restatement was announced. Data on material weaknesses over internal controls reported under SOX (Section 302 or Section 404 reports) were also taken from the AuditAnalytics database. We considered a firm as having ineffective controls if it disclosed one material weakness or more in internal controls under either of these sections. We obtained data on change of auditor and auditor opinion from Compustat, as well as data necessary to identify firm-years just meeting/beating earnings benchmarks (zero and last-year's EPS). We extracted data on the third benchmark, consensus analyst forecasts, from the Institutional Brokers' Estimate System (I/B/E/S). We calculated the consensus earnings forecast as the mean of all forecasts announced in the month preceding that of the earnings announcement. We compared earnings forecast to actual earnings taken from the I/B/E/S, because these data are more likely than the Compustat data to be consistent with the forecast in terms of the treatment of extraordinary items and special items. We obtained financial data from the Compustat industrial annual file and stock return information from the CRSP monthly file. Table 1 depicts all the variable definitions.

[Table 1 about here]

Panel A of Table 2 reports descriptive statistics of RSCORE. The mean value of RSCORE is -0.325 and, as expected, the distribution of RSCORE is skewed to the right. As for the components of RSCORE, being indicator variables, their means represent frequency in the sample. The most frequent indicators of low reliability are restatements (RESTATE), recording a mean of 0.149, and meeting/beating earnings benchmarks (MBE), with a mean of 0.103. Less frequent are change of auditor (CHANGE) and ineffective internal controls over financial reporting (MW), which have means of 0.085 and 0.069, respectively. Lastly, the occurrence of auditor adverse, qualified, or no opinion (OPINION) is rare, reflected by a mean of about 0.001. These frequencies are generally consistent with findings of prior literature (Butler, Leone, and Willenborg 2004; Kim and Park 2006; Ashbaugh-Skaife, Collins, Kinney, and Lafond 2008; Ashbaugh-Skaife, Collins, Kinney, and Lafond 2009; Zang 2012).

Panel B of Table 2 reports Pearson (upper diagonal) and Spearman (lower diagonal) correlations among the five indicators. The correlations between the

indicators comprising RSCORE are small, indicating that each indicator captures different signs of absence of completeness, neutrality, or freedom from errors. Panel C of Table 2 presents the pattern of RSCORE in our sample observations. We find that 72.7% of the observations have no adverse indicators of unreliability, whereas 22.6% have a single adverse indicator of unreliability. The remaining 4.7% of the sample have two indicators or more, suggesting serious reliability problems. The columns on the right side of the panel indicate a reasonable distribution of the five indicators among firms with one to four adverse incidents (where the values of RSCORE are -1 to -4, respectively).

[Table 2 about here]

3.3. Extending the standard value-relevance tests

The reliability measure allows for extending the standard value-relevance tests in two ways. First, we classify our sample observations into two groups. We utilize RSCORE levels to separate between firm-year observations with no signal of weak reliability, $RSCORE=0$, from observations with signals of weak reliability, $RSCORE<0$. For observations in each of the two groups, we estimate the standard value-relevance regression model in its simplest form:

$$RET_t = \alpha + \beta_1 \Delta ERN_t + \varepsilon_t. \quad (1)$$

We use this simple model because earnings are the summary accounting variable that aggregate revenues and expenses. Earnings surprises are interpreted as value relevant if they influence investors' valuation of securities in decisions to buy or sell stocks. A vast body of empirical accounting research utilizes regressions of stock returns on earnings surprises (and earnings levels) to infer value-relevance. A higher ERC suggests more useful reported earnings for security valuation. Verifying that the findings are independent of the measurement of stock returns, we use two alternative variables of stock returns: raw stock returns (e.g., Amir, Harris, and Venuti 1993; Harris, Lang, and Möller 1994; Barth and Clinch 1998; Lev and Zarowin 1999), and market-adjusted stock returns (e.g., Amir and Lev 1996; Francis and Schipper 1999; Weiss, Naik, and Tsai 2008).

Next, we extend the standard value relevance test to gain further insights on the impact of reliability on the usefulness of reported earnings. This extended model disentangles the effects of reliability of relevance as follows:

$$RET_t = \alpha_1 + \beta_1 \Delta ERN_t + \beta_2 RSCORE_t + \beta_3 \Delta ERN_t \cdot RSCORE_t + \varepsilon_t. \quad (2)$$

As before, we utilize raw returns and market-adjusted returns in estimating the model. To increase the confidence in our findings, two analogous versions of the two regression models are estimated. We estimate a pooled cross-sectional regression model, with firm effects, year effects, and both firm and year clustering (Gow, Ormazabal and Taylor 2010). To the extent that stock returns are serially uncorrelated, we also use the Fama-MacBeth procedure for estimating the regression models. We apply the extended value-relevance tests for disentangling

relevance apart from reliability by in two contexts: losses and accounting estimates.

3.4. The determinants of poor reliability

We start by confirming that both contexts we are examining, losses and accounting estimates, are associated with low reliability which affects the results of the standard value-relevance test, as detailed in Sections 4 and 5 below. For this purpose, we employ a cross-sectional regression model in which RSCORE, our measure of reliability, is the independent variable, and the explanatory variables include a dummy variable for loss observations (LOSS, equal to one for firm-years reporting a loss, otherwise zero) and a variable reflecting the number of accounting estimates in the financial statement (#EST).⁸ The regression also incorporates plentiful of other variables associated in the literature with low reliability, such as the size of the firm, book-to-market value of equity, free cash flow, the number of segments, whether the auditor is one of the Big-4, etc. The regression model is as follows:

$$RSCORE_t = \alpha_1 + \beta_1 LOSS_t + \beta_2 \#EST_t + \beta_3 SIZE_t + \beta_4 BV_MV_t + \beta_5 FCF_t + \beta_6 GROWTH_t + \beta_7 AGE_t + \beta_8 SEG_t + \beta_9 BIG_t + \varepsilon_t. \quad (3)$$

The estimation includes fixed firm and year effects. Table 3 reports the results. The coefficient on LOSS is -0.023 in the specification using both variables of interest, and highly significant (p-value=0.001). This result suggests that losses are associated with low reliability, as expected. Similarly, the coefficient of #EST is -0.014 (p-value<0.001), indicating that accounting estimates are also associated with low reliability.

Generally, signs of control variables match their expected effect on reliability, as explored by prior studies. The coefficients on variables for the size of the firm, its free cash flow, its age and the presence of a Big-4 auditor are all positive and significant, suggesting they contribute to reliability. Conversely, the coefficient on the number of segments is negative, indicating it hampers reliability.

[Table 3 about here]

4. Relevance and reliability of profits versus losses

Prior studies utilize the standard value-relevance framework and find that the return-earnings relation for loss firms is much weaker than that for profit firms (Hayn 1995; Collins, Pincus, and Xie 1999; Joos and Plesko 2005; Li 2016; He, Tang and Wong 2018). A lower ERC in the standard value-relevance framework suggests that losses are less useful for investment decision making than profits. The findings are attributed to the market's perception of losses as being transitory. The explanation lies in the abandonment option, whereby firms with losses are more likely to curtail operations (Hayn 1995; Lawrence, Sloan, and Sun 2017).

⁸ See Section 5 for the list of accounting estimates counted in financial statements.

Following a similar path, Balakrishnan, Bartov, and Faurel (2010) reliability report that earnings surprises of loss firms are substantially larger than those of profit firms, indicating weaker relevance.

However, other studies documented signals of weak reliability in loss firms (e.g., Doyle, Ge, and McVay 2007; Ashbaugh-Skaife, Collins, Kinney 2007; Larcker, Richardson, and Tuna 2007). Since value-relevance tests are joint tests of relevance and reliability, they do not provide means for inferring which of the two characteristics of useful information is lacking in loss firms (or, perhaps both). To examine this question, we utilize the reliability measure and the extended value-relevance tests for gaining insights on each of the two characteristics in profit reports versus loss reports.

In the first test we classify our sample observations into four portfolios: profit firms with high reliability ($RSCORE=0$), profit firms with low reliability ($RSCORE<0$), loss firms with high reliability ($RSCORE=0$) and loss firms with low reliability ($RSCORE<0$). We then estimate equation (1) for each firm category separately.

Table 4 reports estimation results, where Panel A presents the results of pooled estimation and Panel B reports the results of the Fama-MacBeth estimation. In Panel A, for the estimation using raw results, the estimated ERC for profit firms with high reliability is 0.810 and the estimated ERC for profit firms with low reliability is 0.691, both highly significant ($p\text{-value}<0.001$). The difference between the ERCs, 0.119, is significant ($p\text{-value}=0.001$), indicating that reliability enhances the usefulness of reported earnings for profit firms. By contrast, the estimated ERC for loss firms with high reliability is 0.362 and the estimated ERC for loss firms with low reliability is also 0.366, both highly significant ($p\text{-value}<0.001$). Importantly, the difference between the ERCs is zero and insignificant ($p\text{-value}=0.994$), indicating that reliability has no significant impact on the ERC for loss firms.

Comparing the estimated ERCs between profit and loss firms, we find significantly lower ERCs for loss firms than for profit firms when reliability is high (0.362 and 0.810, respectively, $p\text{-value}<0.001$). Similarly, we find significantly lower ERCs for loss firms than for profit firms when reliability is low (0.366 and 0.691, respectively, $p\text{-value}<0.001$). These findings indicate a higher ERC in profit firms compared with loss firms after controlling for the level of reliability. This result indicates that reported earnings in profit firms are more useful than in loss firms, after controlling for RSCORE. The result confirms the argumentation in Hayn (1995) and subsequent studies. Results from using market-adjusted returns for estimating equation (1) are essentially the same, and so are the results using Fama-MacBeth procedure reported in Panel B.

[Table 4 about here]

Next, we employ the extended value-relevance test, described in Section 3.3, to disentangle the effects of relevance and reliability on the usefulness of financial statements of profit versus loss firms. Estimation results of equation (2) are reported in Table 5, where Panel A reports results of pooled estimation and Panel B reports results of Fama-MacBeth estimation. For raw stock returns, the coefficient on earnings surprise (ΔERN) of profit firms is 0.803, more than twice the corresponding coefficient of loss firms, which is 0.353. Since this model

controls for reliability, the findings suggest that relevance of profits is higher than relevance of losses, even after considering their dissimilar reliability. Turning to the interaction between the two characteristics, the coefficient for profit firms is 0.080 and significant (p-value=0.003), indicating that higher values of RSCORE increase the association between Δ ERN and stock returns. However, for loss firms the interaction coefficient is -0.028 and insignificant (p-value=0.264), indicating that higher reliability have an insignificant impact on the association between Δ ERN and stock returns. We present similar findings for market-adjusted returns. Additionally, results from estimating equation (2) using the Fama-MacBeth procedure are reported in Panel B of Table 5. The results are essentially the same.

[Table 5 about here]

Overall, the results indicate that loss reports are significantly less reliable and significantly less relevant than profit reports. Moreover, the results suggest that if the level of relevance is sufficient, as is the case in profit firms, increasing reliability is expected to enhance the usefulness of reported earnings. This conclusion is consistent with SFAC 8 (QC17). In contrast, if reported earnings in loss firms have a low, insufficient level of relevance, reliability is unlikely to enhance their usefulness.

5. Relevance and reliability of accounting estimates

In this section, we further explore the extent to which accounting estimates influence reliability and relevance. The FASB encourages firms to report accounting estimates because they increase the relevance of accounting information (IFRS Memorandum 2005; Johnson 2005). However, when considering reliability, prior studies find that accounting latitude leads to biases and manipulations of earnings (see Beyer, Cohen, Lys, and Walther, 2010, for a review), which are likely to impede reliability.⁹ Specifically, Lev, Li, and Sougiannis (2010, p. 780) point out that "*accounting estimates . . . introduce a considerable and unknown degree of noise, and perhaps bias, to financial information, detracting from their usefulness. . . Add to the above objective difficulties in generating reliable estimates the expected and frequently documented susceptibility of accounting estimates to managerial manipulation, and the consequent adverse impact of estimates on the usefulness of financial information becomes apparent.*"

Based on the FASB's approach, we assume that high reliance on accounting estimates increases relevance of the reports. However, relevance of reported earnings is likely to expand their usefulness only in the presence of sufficient reliability. If relevance is insufficient in the group of weak reliability reports (as in SFAC 8, 2010, QC17), increasing reliability is not expected to enhance the usefulness of reported earnings.

⁹ Prior studies also report that accounting estimates lead to impaired item-specific reliability (Choi, Collins, and Johnson 1997; Barth, Landsman, and Rendleman 1998; Dietrich, Harris, and Muller 2001; Cotter and Richardson 2002; Kallapur and Kwan 2004).

To test this assertion, we follow Lev, Li, and Sougiannis (2010, p. 800) and compile 10 accounting estimates underlying financial information. These estimates are change in inventory, depreciation and amortization, deferred taxes, pension expense, post-retirement benefits, doubtful receivables, restructuring costs, in-process research and development, stock-compensation expense, and asset write-downs. Next, we compute the intensity of accounting estimates (#EST) for each firm-year as the number of estimates recorded in the financial statements out of the 11 on our list. Hence, #EST can take values between zero and 10. Notably, we include in this section only profit firms to prevent the confounding effect of profits versus losses from driving our results.

As we did for profits versus losses, we begin with portfolio analysis in which we use four firm categories: we first classify the sample to low- versus high-intensity of accounting estimates, and then divide each group to high reliability firms (RSCORE=0) and low reliability firms (RSCORE<0).¹⁰ For each of the four firm-categories we estimate equation (1), the standard value-relevance test. As before, we use either raw returns or market-adjusted returns, and employ two estimation methods: pooled and Fama-MacBeth.

Table 6 presents estimation results of all specifications. The Pooled estimation is reported in Panel A and the Fama-Macbeth estimation is reported in Panel B. As the Table demonstrates, the coefficient on earnings surprise (Δ ERN) of high estimate-intensity firms is significantly higher than the corresponding coefficient of low estimate-intensity firms. In Panel A, for the estimation using raw results, the estimated ERC for high estimate-intensity firms with high reliability is 0.847 and the estimated ERC for high estimate-intensity firms with low reliability is 0.703, both highly significant (p-value<0.001). The difference between the ERCs, 0.144, is significant (p-value=0.001), indicating that reliability enhances the usefulness of reported earnings for high estimate-intensity firms. By contrast, the estimated ERC for low estimate-intensity firms with high reliability is 0.631 and the estimated ERC for low estimate-intensity firms with low reliability is also 0.620, both highly significant (p-value<0.001). Importantly, the difference between the ERCs is zero and insignificant (p-value=0.783), indicating that reliability has no significant impact on the ERC for low estimate-intensity firms.

Comparing the estimated ERCs between high and low estimate-intensity firms, we find significantly lower ERCs for low estimate-intensity firms than for high estimate-intensity firms when reliability is high (0.637 and 0.847, respectively, p-value<0.001). Similarly, we find significantly lower ERCs for low estimate-intensity firms than high estimate-intensity firms when reliability is low (0.620 and 0.703, respectively, p-value<0.001). These findings indicate a higher ERC in high estimate-intensity firms compared with low estimate-intensity firms after controlling for the level of reliability. This result indicates that reported earnings in high estimate-intensity firms are more useful than in low estimate-intensity firms, after controlling for RSCORE. Results from using market-adjusted returns for estimating equation (1) are essentially the same, and so are the results using Fama-MacBeth procedure reported in Panel B.

[Table 6 about here]

¹⁰ The low-intensity of accounting estimates category includes all profit observations recording up to three estimates, while low-intensity category includes all profit observations recording at least four estimates.

Our second analysis employs the extended value-relevance test, described in Section 3.3, to disentangle the effects of relevance and reliability on the usefulness of financial statements. Estimation results of equation (2) are reported in Table 7, where Panel A reports results of pooled estimation and Panel B reports results of Fama-MacBeth estimation. For raw stock returns, the coefficient on earnings surprise (ΔERN) of high estimate-intensity firms is 0.835, significantly higher than the coefficient for low estimate-intensity firms, which is 0.648. The findings suggest that relevance of high estimate-intensity is higher than relevance of low estimate-intensity, even after considering their dissimilar reliability. As for the interaction between the two characteristics, the coefficient for high estimate-intensity firms is 0.087 and significant ($p\text{-value}=0.003$), indicating that higher values of RSCORE increase the association between ΔERN and stock returns. However, for low estimate-intensity firms the interaction coefficient is 0.054 and insignificant ($p\text{-value}=0.407$), indicating that higher reliability have an insignificant impact on the association between ΔERN and stock returns. We report similar findings for market-adjusted returns. Furthermore, results from estimating equation (2) using the Fama-MacBeth procedure are essentially the same.

[Table 7 about here]

Overall, the results indicate that low estimate-intensity reports significantly less relevant than high estimate-intensity reports. Moreover, the results suggest that if the level of relevance is sufficient, as is the case in high estimate-intensity firms, increasing reliability is expected to enhance the usefulness of reported earnings. In contrast, if reported earnings in low estimate-intensity firms have a low, insufficient level of relevance, reliability is unlikely to enhance their usefulness. These conclusions are consistent with the ones obtained in our previous analysis of profit versus loss firms.

7. Summary

This study extends the standard value-relevance test in order to enable disentanglement between the distinct effects of relevance and reliability on usefulness of financial reporting. We apply our measure of reliability in two settings, one of them compares between profit and loss firms, and the other compare between high estimate-intensity and low estimate-intensity firms. In both settings, the differential reliability between the opposing firm categories may distort the results of the standard value-relevance test, which does consider the level of reliability.

The findings demonstrate the profits are more relevant than losses, even when accounting for their higher reliability. Furthermore, high estimate-intensity are more relevant than low estimate-intensity firms, controlling for their lower reliability. Moreover, both settings reveal that reliability matters only if the level of relevance is sufficient. In these cases (profits, high estimate-intensity) increasing reliability is expected to enhance the usefulness of reported earnings. However, if reported earnings have a low level of relevance (losses, low estimate-intensity), reliability is unlikely to affect their usefulness.

REFERENCES

- Aboody, D., & Lev, B. (1998). The value-relevance of intangibles: The case of software capitalization. *Journal of Accounting Research*, 36, 161–191. doi:10.2307/2491312
- Amir, E., Harris, T. S., & Venuti, E. K. (1993). A comparison of the value-relevance of U. S. versus Non-U. S. GAAP accounting measures using Form 20-F reconciliations. *Journal of Accounting Research*, 31, 230–264.
- Amir, E., & Lev, B. (1996). Value-relevance of non-financial information: The wireless communications industry. *Journal of Accounting and Economics*, 22, 3–30.
- Ashbaugh-Skaife, H., Collins, D. W., & Kinney, W. R. (2007). The discovery and reporting of internal control deficiencies prior to SOX-mandated audits. *Journal of Accounting and Economics*, 44(1-2), 166–192.
- Ashbaugh-Skaife, H., Collins, D. W., Kinney Jr, W. R., & Lafond, R. (2008). The effect of SOX internal control deficiencies on firm risk and cost of equity. *Journal of Accounting Research*, 83(1), 217–250.
- Ashbaugh-Skaife, H., Collins, D. W., Kinney Jr, W. R., & Lafond, R. (2009). The effect of SOX internal control deficiencies on firm risk and cost of equity. *Journal of Accounting Research*, 47(1), 1–43.
- Balakrishnan, K., Bartov, E., & Faurel, L. (2010). Post loss/profit announcement drift. *Journal of Accounting and Economics*, 50(1), 20–41.
- Barth, M. E. (1994). Value accounting: Evidence from investment securities and the market valuation of banks. *The Accounting Review*, 69(1), 1–25.
- Barth, M.E., Beaver, W.H. and Landsman, W.R., 2001. The relevance of the value-relevance literature for financial accounting standard setting: another view. *Journal of Accounting and Economics*, 31(1), 77-104.
- Barth, M. E., Beaver, W. H., & Landsman, W. R. (2001). The relevance of the value-relevance literature for financial accounting standard setting: Another view. *Journal of Accounting and Economics*, 31, 77–104.
- Barth, M. E., & Clinch, G. (1998). Revalued financial , tangible , and intangible assets : associations with share prices and non-market-based value estimates. *Journal of Accounting Research*, 36, 199–233.
- Barth, M. E., Landsman, W. R., & Rendleman, R. J. (1998). Option pricing-based bond value estimates and a fundamental components approach to account for corporate debt. *The Accounting Review*, 73(1), 73–102.

- Beyer, A., Cohen, D. A., Lys, T. Z., & Walther, B. R. (2010). The financial reporting environment: Review of the recent literature. *Journal of Accounting and Economics*, 50(2-3), 296–343.
- Butler, M., Leone, A. J., & Willenborg, M. (2004). An empirical analysis of auditor reporting and its association with abnormal accruals. *Journal of Accounting and Economics*, 37(2), 139–165.
- Chen, L., Krishna, J., Sami, H., Zhou, H., 2013. Auditor atestation under SOX Section 404 and earnings informativeness. *Auditing: A Journal of Practice & Theory* 32: 61-84.
- Choi, B. (Ben), Collins, D. W., & Johnson, W. B. (1997). Valuation implications of reliability differences: The case of nonpension postretirement obligations. *The Accounting Review*, 72(3), 351–383.
- Choi, S. K., Jeter, C., 1992. The effects of qualified audit opinions on earnings response coefficients. *Journal of Accounting and Economics*, 15: 229-247.
- Clinton, S. B., Pinello, A. S., & Skaife, H. A. (2014). The implications of ineffective internal control and SOX 404 reporting for financial analysts. *Journal of Accounting and Public Policy*, 33(4), 303–327.
- Cohen, D. A., Darrrough, M. N., Huang, R., & Zach, T. (2011). Warranty reserve: contingent liability, information signal, or earnings management tool? *The Accounting Review*, 86(2), 569–604.
- Cohen, D. A., Dey, A., & Lys, T. Z. (2008). Real and accrual-based earnings management in the pre- and post-Sarbanes-Oxley periods. *The Accounting Review*, 83(3), 757–787.
- Collins, D. W., Pincus, M., & Xie, H. (1999). Equity valuation and negative earnings: The role of book value of equity. *The Accounting Review*, 74(1), 29–61.
- Cotter, J., & Richardson, S. (2002). Reliability of asset revaluations: The Impact of appraiser independence. *Review of Accounting Studies*, 7, 435–457.
- Chung, H., & Kallapur, S. (2003). Client importance, nonaudit services, and abnormal accruals. *The Accounting Review*, 78 (4), 931–955.
- Dechow, P., Ge, W., & Schrand, C. (2010). Understanding earnings quality: A review of the proxies, their determinants and their consequences. *Journal of Accounting and Economics*, 50(2-3), 344–401.
- DeFond, M. L., & Jiambalvo, J. (1994). Debt covenant violation and manipulation of accruals. *Journal of Accounting and Economics*, 17, 145–176.
- Dickinson, V., Kimmel, P., & Warfield, T. (2012). The accounting and market consequences of accelerated share repurchases. *Review of Accounting Studies*, 17, 41–71.

- Dietrich, J. R., Harris, M. S., & Muller III, K. A. (2001). The reliability of investment property fair value estimates. *Journal of Accounting and Economics*, 30, 125–158.
- Doyle, J., Ge, W., & McVay, S. (2007). Determinants of weaknesses in internal control over financial reporting. *Journal of Accounting and Economics*, 44(1-2), 193–223.
- Elliot, J. A., & Hanna, D., 1996. Repeated accounting write-offs and the information content of earnings. *Journal of Accounting Research* 34: 135-155.
- Erb, C., & Pelger, C. (2015). "Twisting words"? A study of the construction and reconstruction of reliability in financial reporting. *Accounting , Organizations and Society*, 40, 13–40.
- Erickson, M., Hanlon, M., & Maydew, E. L. (2006). Is there a link between executive equity incentives and accounting fraud? *Journal of Accounting Research*, 44(1), 113–143.
- Financial Accounting Standards Board (FASB). 1980. Qualitative characteristics of accounting information. Statement of Financial Accounting Concepts No. 2. Norwalk, CT: FASB.
- Financial Accounting Standards Board (FASB). 2010. Conceptual framework for financial reporting. Statement of Financial Accounting Concepts No. 8. Norwalk, CT: FASB.
- Francis, J., Lafond, R., Olsson, P., & Schipper, K. (2005). The market pricing of accruals quality. *Journal of Accounting and Economics*, 39(2), 295–327.
- Francis, J., & Schipper, K. (1999). Have Financial Statements Lost Their Relevance? *Journal of Accounting Research*, 37(2), 319–352.
- Gompers, P., Ishii, J., & Metrick, A. (2003). Corporate governance and equity prices. *The Quarterly Journal of Economics*, 118(1), 107–156.
- Graham, J. R., Harvey, C. R., & Rajgopal, S. (2005). The economic implications of corporate financial reporting. *Journal of Accounting and Economics*, 40(1-3), 3–73.
- Hackenbrack, E., Hogan, E., 2002. Market response to earnings surprises conditional on reasons for an auditor change. *Contemporary Accounting Research* 19: 195-223.
- Harris, T. S., Lang, M., & Möller, H. P. (1994). The Value-relevance of German Accounting Measures: An Empirical Analysis. *Journal of Accounting Research*, 32(2), 187–209.
- Hayn, C. (1995). The information content of losses. *Journal of Accounting and Economics*, 20, 125–153.

- He, W., Tan, H. C., & Wong, L. (2018). Return windows and the value relevance of earnings. *Accounting & Finance*.
- Holthausen, R. W., & Watts, R. L. (2001). The relevance of the value-relevance literature for financial accounting standard setting. *Journal of Accounting and Economics*, 31, 3–75.
- Jiang, J. (Xuefeng). (2008). Beating earnings benchmarks and the cost of debt. *The Accounting Review*, 83(2), 377–416.
- Johnson, V. E., Khurana, I. K., & Reynolds, J. K. (2002). Audit-firm tenure and the quality of financial reports. *Contemporary Accounting Research*, 19(4), 637–660.
- Joos, P. and Plesko, G.A., 2005. Valuing loss firms. *The Accounting Review*, 80(3), 847-870.
- Joyce, E. J., Libby, R., & Sunder, S. (1982). Using the FASB's Qualitative Characteristics in Accounting Policy Choices. *Journal of Accounting Research*, 20(2), 654–675.
- Kadous, K., Koonce, L., & Thayer, J. M. (2012). Do financial statement users judge relevance based on properties of reliability? *The Accounting Review*, 87(4), 1335–1356.
- Kallapur, S., & Kwan, S.Y.S. (2004). The value-relevance and reliability of brand assets recognized by U.K. Firms. *The Accounting Review*, 79(1), 151–172.
- Kim, Y., & Park, M. S. (2006). Auditor changes and the pricing of seasoned equity offers. *Accounting Horizons*, 20(4), 333–349. doi:10.2308/acch.2006.20.4.333
- Kinney, W. R., & McDaniel, L. S. (1989). Characteristics of firms correcting previously reported quarterly earnings. *Journal of Accounting and Economics*, 11, 71–93.
- Kothari, S. P. (2001). Capital markets research in accounting. *Journal of Accounting and Economics*, 31(1), 105-231.
- Kothari, S. P., Laguerre, T. E., & Leone, A. J. (2002). Capitalization versus expensing: evidence on the uncertainty of future earnings from capital expenditures versus R&D outlays. *Review of Accounting Studies*, 7, 355–382.
- Krishnan, J. (2005). Audit committee quality and internal control : an empirical analysis. *The Accounting Review*, 80(2), 649–675.
- Larcker, D. F., Richardson, S. A., & Tuna, I. (2007). Corporate governance, accounting outcomes, and organizational performance. *The Accounting Review*, 82(4), 963–1008.

- Lawrence, A., Sloan, R. and Sun, E., 2017. Why Are Losses Less Persistent Than Profits? Curtailments vs. Conservatism. *Management Science*. forthcoming.
- Lev, B., Li, S., & Sougiannis, T. (2010). The usefulness of accounting estimates for predicting cash flows and earnings. *Review of Accounting Studies*, 15(4), 779–807.
- Lev, B., & Thiagarajan, S. R. (1993). Fundamental information analysis. *Journal of Accounting Research*, 31(2), 190–215.
- Lev, B., & Zarowin, P. (1999). The boundaries of financial reporting and how to extend them. *Journal of Accounting Research*, 37(2), 353–385.
- Li, B., (2016) Separating information about cash flows from information about risk in losses. Working paper. Available at SSRN: <https://ssrn.com/abstract=2197550> or <http://dx.doi.org/10.2139/ssrn.2197550>
- Lougee, B. A., & Marquardt, C. A. (2004). Earnings informativeness and strategic disclosure: An empirical examination of "pro forma" earnings. *The Accounting Review*, 79(3), 769–795.
- Maines, L. A., & Whalen, J. M. (2006). The nature of accounting information reliability: inferences from archival and. *Accounting Horizons*, 20(4), 399–425.
- Myers, J., Myers, L., and Omer, T. (2003). Exploring the term of the auditor–client relationship and the quality of earnings: A case for mandatory auditor rotation? *The Accounting Review*, 78 (3), 779–799.
- Ogneva, M., Subramanyam, K. R., & Raghunandan, K. (2007). and cost of control weakness internal from SOX section equity: evidence 404 disclosures. *The Accounting Review*, 82(5), 1255–1297.
- Piotroski, J. D. (2000). Value Investing: The Use of Historical Financial Statement Information to Separate Winners from Losers. *Journal of Accounting Research*, 38, 1–41.
- Public Company Accounting Oversight Board (PCAOB). (2007). *An Audit of Internal Control Over Financial Reporting That Is Integrated with An Audit of Financial Statements*, Auditing Standard No. 5, Washington D.C.
- Romanus, R. N., Maher, J. J., & Fleming, D. M. (2008). Auditor industry specialization, auditor changes, and accounting restatements. *Accounting Horizons*, 22(4), 389–413.
- Roychowdhury, S. (2006). Earnings management through real activities manipulation. *Journal of Accounting and Economics*, 42(3), 335–370.

- Schneider, A., & Church, B. K. (2008). The effect of auditors' internal control opinions on loan decisions. *Journal of Accounting and Public Policy*, 27(1), 1–18.
- Singer, Z., You, H., (2011). The effect of Section 404 of the Sarbanes-Oxley Act on earnings quality. *Journal of Accounting, Auditing & Finance*, 26: 556-589.
- Stanley, J. D., & Todd DeZoort, F. (2007). Audit firm tenure and financial restatements: An analysis of industry specialization and fee effects. *Journal of Accounting and Public Policy*, 26(2), 131–159.
- Stice, J. D. (1991). Using financial information to identify pre-engagement factors associated with lawsuits against auditors. *The Accounting Review*, 66(3), 516–533.
- Subramanyam, K. R. (1996). The pricing of discretionary accruals. *Journal of Accounting and Economics*, 22, 249–281.
- Teoh, S., & Wong, T. (1993). Perceived auditor quality and the earnings response coefficient. *The Accounting Review*, 68(2), 346–366.
- Weiss, D., Naik, P. A., & Tsai, C. L. (2008). Extracting forward-looking information from security prices: A new approach. *The Accounting Review*, 83(4), 1101–1124.
- Wilson. W., (2008). An empirical analysis of the decline in the information content of earnings following restatements. *The Accounting Review* 83: 519-548.
- Zang, A. Y. (2012). Evidence on the trade-off between real activities manipulation and accrual-based earnings management. *The Accounting Review*, 87(2), 675–703.

TABLE 1
Variable Definitions

Variable (firm subscript omitted)	Description (Compustat data items in brackets)
AGE	= The number of years firm <i>i</i> has been publicly traded.
BIG	= A dummy variable equal to 1 if the firm auditing firm <i>i</i> in year <i>t</i> is one of the Big-4 audit firms, zero otherwise.
BV_MV	= The ratio between firm <i>i</i> 's book value of equity (CEQ_t) and market value of equity ($PRCC_F_t * CSHO_t$).
CHANGE	= A dummy variable equal to 1 if firm <i>i</i> changed auditor in year <i>t</i> , zero otherwise.
ERN	= Earnings before extraordinary items scaled by market value of equity at the beginning of year <i>t</i> ($IB_t / (PRCC_F_{t-1} * CSHO_{t-1})$).
Δ ERN	= Change in ERN, equal to $ERN_t - ERN_{t-1}$
#EST	= The number of accounting estimates firm <i>i</i> recorded in year <i>t</i> out of the following 11: change in inventory, depreciation and amortization, deferred taxes, pension expense, post-retirement benefits, doubtful receivables, restructuring costs, in-process research and development, stock-compensation expenses, asset write-downs, and goodwill impairment.
FCF	= Firm <i>i</i> 's free cash flow, calculated as the difference between operating cash flow ($OANCF_t$) and average capital expenditure ($CAPX_t$) over years <i>t</i> and <i>t-1</i> , deflated by total assets at the beginning of year <i>t</i> (AT_{t-1}).
Δ RSCORE	= Change in RSCORE, equal to $RSCORE_t - RSCORE_{t-1}$
GROWTH	= The percentage change in firm <i>i</i> 's sales ($SALE_t$) from year <i>t-1</i> to year <i>t</i> .
LEV	= Financial leverage equal to the sum of long-term debt (Compustat $DLTT_t$) and debt in current liabilities (Compustat DLC_t) divided by the sum of the long-term debt, debt in current liabilities, and market value of equity.
LOSS	= A dummy variable equal to 1 if firm <i>i</i> in year <i>t</i>

		recorded negative earnings before extraordinary items, zero otherwise.
MBE	=	A dummy variable equal to 1 if firm <i>i</i> just meets/beats at least one of three earnings benchmarks in year <i>t</i> , zero otherwise. Observations suspected of indicating just beating/meeting the zero benchmark are defined as firm-years with earnings before extraordinary items over lagged assets (IB_t / AT_{t-1}) between 0 and 0.005. Observations suspected of indicating just beating/meeting last-year's earnings are firm-years with change in basic EPS excluding extraordinary items from last year ($EPSPX_t - EPSPX_{t-1}$) between 0 and 2 cents. Observations suspected of indicating just beating/meeting analyst forecast consensus are firm-years with an actual EPS less the analyst forecast consensus outstanding prior to the earnings announcement date between 0 and 1 cent.
ME	=	A dummy variable equal to 1 if firm <i>i</i> reports ineffective controls under Section 302 or Section 404 in year <i>t</i> , zero otherwise.
MVE	=	Firm <i>i</i> 's market value of equity in millions of dollars in year <i>t</i> , calculated as the product of the fiscal year-end closing share price ($PRCC_F_t$) and common shares outstanding ($CSHO_t$).
NON_REC_D	=	A dummy variable equal to 1 if in year <i>t</i> firm <i>i</i> has two non-recurring estimates or more, zero otherwise.
#NON_REC_EST	=	The number of non-recurring estimates firm <i>i</i> recorded in year <i>t</i> out of the following five: restructuring costs, in-process research and development, stock-compensation expenses, asset write-downs, and goodwill impairment.
OPINION	=	A dummy variable equal to 1 if auditor of firm <i>i</i> issued a qualified, adverse or no opinion in year <i>t</i> ($AUOP$ equals 2, 3 or 5), zero otherwise.
#REC_EST	=	The number of recurring estimates firm <i>i</i> recorded in year <i>t</i> out of the following six: change in inventory, depreciation and amortization, deferred taxes, pension expense, post-retirement benefits, and doubtful receivables.

RESTATE	=	A dummy variable equal to 1 if firm i filed a restatement in year t , zero otherwise.
RET	=	Annual stock return computed over a 12-month period starting at the beginning of the fourth month of the current fiscal year, either raw (RET_RAW) or market adjusted (RET_MA).
RET_MA	=	Annual market-adjusted stock return computed over a 12-month period starting at the beginning of the fourth month of the current fiscal year.
RET_RAW	=	Annual raw stock return computed over a 12-month period starting at the beginning of the fourth month of the current fiscal year.
SEG	=	The natural logarithm of firm i 's number of operating segments reported by the Compustat Segments database.
SIZE	=	The natural logarithm of firm i 's market value of equity in millions of dollars in year t , calculated as the product of the fiscal year-end closing share price (PRCC_F $_t$) and common shares outstanding (CSHO $_t$).
STDCFO	=	Standard deviation of cash flow from operations (Compustat OANCF) deflated by total assets, computed over the period $t-5$ to $t-1$.

TABLE 2
Descriptive Statistics

Panel A – Descriptive statistics

<u>Variable</u>	<u>N</u>	<u>Mean</u>	<u>Q1</u>	<u>Median</u>	<u>Q3</u>	<u>Std Dev</u>	<u>Skewness</u>
RSCORE	40,542	-0.325	-1.000	-	-	0.580	-1.798
RESTATE	40,542	0.149				0.356	1.972
MW	40,542	0.069				0.253	3.414
MBE	40,542	0.103				0.304	2.609
CHANGE	40,542	0.085				0.278	2.985
OPINION	40,542	0.000				0.017	58.101
ΔERN	40,542	0.023	-0.022	0.007	0.038	0.216	
LOSS	40,542	0.300	-	-	1.000	0.458	
#EST	40,542	5.285	4.000	5.000	6.000	1.659	
SIZE	40,542	6.315	4.878	6.263	7.668	2.047	
BV_MV	40,542	0.604	0.280	0.489	0.777	0.560	
FCF	40,542	0.019	-0.028	0.039	0.087	0.178	
GROWTH	40,542	0.148	-0.025	0.080	0.215	0.435	
AGE	40,542	2.793	2.303	2.708	3.296	0.692	
SEG	40,542	1.331	0.693	1.386	1.946	0.768	
BIG	40,542	0.797	1.000	1.000	1.000	0.402	
STDCFO	32160	0.126	0.033	0.063	0.131	0.205	
RET_RAW	40,542	0.160	-0.213	0.077	0.399	0.557	
RET_MA	40,542	0.058	-0.225	-0.006	0.246	0.448	

Panel B – Correlation matrix

	<u>RSCORE</u>	<u>RESTATE</u>	<u>MW</u>	<u>MBE</u>	<u>CHANGE</u>	<u>OPINION</u>	<u>ΔERN</u>
RSCORE	1.000	-0.203 <i><0.001</i>	-0.484 <i><0.001</i>	-0.550 <i><0.001</i>	-0.512 <i><0.001</i>	-0.031 <i><0.001</i>	0.012 <i>0.016</i>
RESTATE	-0.203 <i><0.001</i>	1.000	0.208 <i><0.001</i>	0.003 <i>0.497</i>	0.032 <i><0.001</i>	0.001 <i>0.863</i>	-0.013 <i>0.008</i>
MW	-0.484 <i><0.001</i>	0.208 <i><0.001</i>	1.000	-0.017 <i>0.001</i>	0.059 <i><0.001</i>	0.012 <i>0.013</i>	-0.030 <i><0.001</i>
MBE	-0.550 <i><0.001</i>	0.003 <i>0.497</i>	-0.017 <i>0.001</i>	1.000	-0.001 <i>0.774</i>	0.004 <i>0.470</i>	-0.006 <i>0.259</i>
CHANGE	-0.512 <i><0.001</i>	0.032 <i><0.001</i>	0.059 <i><0.001</i>	-0.001 <i>0.774</i>	1.000	-0.000 <i>0.987</i>	0.010 <i>0.049</i>
OPINION	-0.031 <i><0.001</i>	0.001 <i>0.863</i>	0.012 <i>0.013</i>	0.004 <i>0.470</i>	-0.000 <i>0.987</i>	1.000	-0.001 <i>0.775</i>
ΔERN	0.012 <i>0.016</i>	-0.013 <i>0.008</i>	-0.030 <i><0.001</i>	-0.006 <i>0.259</i>	0.010 <i>0.049</i>	-0.001 <i>0.775</i>	1.000

Panel C – RSCORE distribution

	RSCORE	Obs.	% of the sample	Total Number of Incidents	RESTATE	MW	MBE	CHANGE	OPINION
Weak reliability	-4	10	0.0%	40	10	10	10	10	-
	-3	211	0.5%	633	184	192	97	159	1
	-2	1,669	4.1%	3,338	970	994	604	765	5
	-1	<u>9,160</u> 11,050	<u>22.6%</u> 27.3%	9,160	1,601	1,585	3,472	2,496	6
Reliable	0	29,492	72.7%	-	-	-	-	-	-
	Total	40,542	100.0%	13,171	2,765	2,781	4,183	3,430	12

Panel A presents descriptive statistics of RSCORE and its components (RSCORE counts the number of adverse indicators recorded *with a negative sign*; hence, RSCORE has a negative mean, whereas indicator variables have positive means). Panel B presents Pearson (upper diagonal) and Spearman (lower diagonal) correlations between the components of RSCORE (p-values are in parentheses). Panel C presents the distribution of RSCORE values and its components in the sample.

Definitions of all variables are in Table 1.

TABLE 3
Determinants of Poor Reliability

Intercept	-0.581 (<0.001)	-0.562 (<0.001)	-0.543 (<0.001)
LOSS	-0.022 (0.001)		-0.023 (0.001)
#EST		-0.014 (<0.001)	-0.014 (<0.001)
SIZE	0.011 (<0.001)	0.011 (<0.001)	0.012 (<0.001)
BV_MV	-0.005 (0.412)	-0.007 (0.188)	-0.005 (0.396)
FCF	0.034 (0.044)	0.060 (<0.001)	0.043 (0.013)
GROWTH	0.014 (0.041)	0.011 (0.107)	0.009 (0.177)
AGE	0.039 (<0.001)	0.048 (<0.001)	0.046 (<0.001)
SEG	-0.036 (<0.001)	-0.028 (<0.001)	-0.029 (<0.001)
BIG	0.145 (<0.001)	0.153 (<0.001)	0.150 (<0.001)
Firm effects	YES	YES	YES
Year effects	YES	YES	YES
R ²	0.043	0.044	0.044
Obs.	40,252	40,252	40,252

The table presents coefficient estimates of cross-sectional regressions of RSCORE on LOSS and on #EST, the number of accounting estimates reported by firm i in year t . The full regression model is as follows:

$$RSCORE_t = \alpha_1 + \beta_1 LOSS_t + \beta_2 \#EST_t + \beta_3 SIZE_t + \beta_4 BV_MV_t + \beta_5 FCF_t + \beta_6 GROWTH_t + \beta_7 AGE_t + \beta_8 SEG_t + \beta_9 BIG_t + \varepsilon_t. \quad (3)$$

Definitions of all variables are in Table 1. P-values are in parentheses

TABLE 4
Profits versus Losses – Portfolio Analysis

Panel A – pooled estimation

Portfolio		Raw returns			Market adjusted returns		
		PROFIT	LOSS	Difference	PROFIT	LOSS	Difference
High RSCORE=0	Coef	0.810	0.362	0.448	0.765	0.354	0.411
	p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	Obs.	20,835	8,657		20,835	8,657	
Low RSCORE<0	Coef	0.691	0.366	0.325	0.669	0.352	0.317
	p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	Obs.	7,537	3,513		7,537	3,513	
	Difference	0.119	-0.004		0.096	0.002	
	p-value	(0.001)	(0.959)		(0.003)	(0.958)	

Panel B – Fama-MacBeth estimation

Portfolio		Raw returns			Market-adjusted returns		
		PROFIT	LOSS	Difference	PROFIT	LOSS	Difference
High RSCORE=0	Coef	0.868	0.328	0.540	0.809	0.325	0.484
	p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	Obs.	20,835	8,657		20,835	8,657	
Low RSCORE<0	Coef	0.703	0.328	0.375	0.688	0.320	0.368
	p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	Obs.	7,537	3,513		7,537	3,513	
	Difference	0.164	<0.001		0.121	0.005	
	p-value	(0.046)	(0.994)		(0.061)	(0.912)	

Panel A presents the coefficient estimate β from estimating a cross-sectional value-relevance regression in portfolios using pooled estimation. The portfolios are classified by *levels* of the reliability measure RSCORE and by profitability (profits vs. losses). p-values are reported in parentheses. The model is as follows:

$$RET_t = \alpha + \beta \Delta E_t + \varepsilon_t. \quad (1)$$

Panel B presents similar coefficient estimates using the Fama-MacBeth estimation procedure. P-values are in parentheses.

TABLE 5
Profits versus Losses – Regression Models

Panel A – Pooled estimation

	Raw returns			Market-adjusted returns		
	<u>PROFIT</u>	<u>LOSS</u>	<u>Difference</u>	<u>PROFIT</u>	<u>LOSS</u>	<u>Difference</u>
Intercept	-0.074 (<0.001)	-0.300 (<0.001)		0.129 (<0.001)	-0.146 (<0.001)	
Δ ERN	0.803 (<0.001)	0.353 (<0.001)	0.450 (<0.001)	0.762 (<0.001)	0.345 (<0.001)	0.417 (<0.001)
RSCORE	0.024 (<0.001)	0.024 (0.003)		0.023 (<0.001)	0.020 (0.006)	
Δ ERN*RSCORE	0.080 (0.003)	-0.028 (0.264)		0.069 (0.005)	-0.024 (0.303)	
Firm effects	YES	YES		YES	YES	
Year effects	YES	YES		YES	YES	
R ²	0.334	0.288		0.113	0.090	
Obs.	28,372	12,170		28,372	12,170	

Panel B – Fama-MacBeth estimation

	Raw returns			Market-adjusted returns		
	<u>PROFIT</u>	<u>LOSS</u>	<u>Difference</u>	<u>PROFIT</u>	<u>LOSS</u>	<u>Difference</u>
Intercept	0.167 (0.078)	0.061 (0.617)		0.072 (0.004)	-0.035 (0.563)	
Δ ERN	0.866 (<0.001)	0.319 (<0.001)	0.547 (<0.001)	0.810 (<0.001)	0.318 (<0.001)	0.492 (<0.001)
RSCORE	0.024 (0.019)	0.024 (0.003)		0.022 (0.023)	0.020 (0.002)	
Δ ERN*RSCORE	0.161 (0.020)	-0.027 (0.488)		0.147 (0.029)	-0.018 (0.589)	
R ²	0.069	0.042		0.075	0.045	
Obs.	28,372	12,170		28,372	12,170	

The tables present coefficient estimates and p-values in parentheses of standard cross-sectional value-relevance regressions with an interaction with RSCORE (reliability levels), measured separately for profit firms and loss firms. The model is as follows:

$$RET_t = \alpha + \beta_1 \Delta ERN_t + \beta_2 RSCORE_t + \beta_3 \Delta ERN_t \cdot RSCORE_t + \varepsilon_t \quad (2)$$

Panel A reports results obtained using pooled estimation with firm and year effects and Panel B reports results obtained using Fama-MacBeth estimations (year-by-year).

Definitions of all variables are in Table 1.

TABLE 6
The Impact of Accounting Estimates – Portfolio Analysis

Panel A – Pooled estimation

		Raw returns			Market adjusted returns		
		LOW	HIGH		LOW	HIGH	
		<u>EST</u>	<u>EST</u>	<u>Difference</u>	<u>EST</u>	<u>EST</u>	<u>Difference</u>
High	Coef	0.631	0.847	-0.216	0.596	0.802	-0.206
RSCORE=0	p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
	Obs.	2,459	18,376		2,459	18,376	
Low	Coef	0.620	0.703	-0.083	0.584	0.684	-0.100
RSCORE<0	p-value	(<0.001)	(<0.001)	(0.282)	(<0.001)	(<0.001)	(0.167)
	Obs.	797	6,740		797	6,740	
	Difference	0.011	0.144		0.012	0.118	
	p-value	(0.783)	(<0.001)		(0.840)	(<0.001)	

Panel B – Fama-MacBeth estimation

		Raw returns			Market adjusted returns		
		LOW	HIGH		LOW	HIGH	
		<u>EST</u>	<u>EST</u>	<u>Difference</u>	<u>EST</u>	<u>EST</u>	<u>Difference</u>
High	Coef	0.558	0.939	-0.381	0.528	0.877	0.003
RSCORE=0	p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(0.002)
	Obs.	2,459	18,376		2,459	18,376	
Low	Coef	0.668	0.725	-0.057	0.708	0.709	-0.001
RSCORE<0	p-value	(0.002)	(<0.001)	(0.714)	(0.009)	(<0.001)	(0.997)
	Obs.	797	6,740		797	6,740	
	Difference	-0.110	0.214		-0.180	0.168	
	p-value	(0.557)	(0.046)		(0.452)	(0.113)	

The table presents the coefficient estimate β from estimating a cross-sectional value-relevance regression in portfolios. The portfolios include all profit firms in the sample and classified by the reliability measure RSCORE and by number of estimates. LOW EST includes all profit observations recording up to three estimates, while HIGH EST includes all profit observations recording at least four estimates. The model is as follows:

$$RET_t = \alpha + \beta \Delta ERN_t + \varepsilon_t \quad (1)$$

Panel A reports results obtained using pooled estimation with firm and year effects and Panel B reports results obtained using Fama-MacBeth estimations (year-by-year). p-values are reported in parentheses.

Definitions of all variables are in Table 1.

TABLE 8
The Impact of Accounting Estimates – Regression Analysis

Panel A – Pooled estimation

	Raw Returns			Market Adjusted Returns		
	LOW	HIGH	<u>Difference</u>	LOW	HIGH	<u>Difference</u>
	<u>EST</u>	<u>EST</u>		<u>EST</u>	<u>EST</u>	
Intercept	0.009 (0.653)	-0.093 (<0.001)		0.239 (<0.001)	0.104 (<0.001)	
Δ ERN	0.648 (<0.001)	0.835 (<0.001)	-0.187 (<0.001)	0.610 (<0.001)	0.794 (<0.001)	-0.184 (<0.001)
RSCORE	0.029 (0.062)	0.023 (<0.001)		0.027 (0.056)	0.021 <.0001	
Δ ERN*RSCORE	0.054 (0.407)	0.087 (0.003)		0.045 (0.460)	0.076 (0.005)	
Firm effects	YES	YES		YES	YES	
Year effects	YES	YES		YES	YES	
R ²	0.347	0.334		0.137	0.112	
Obs.	3,256	25,116		3,256	25,116	

Panel B – Fama-MacBeth estimation

	Raw Returns			Market Adjusted Returns		
	LOW	HIGH	<u>Difference</u>	LOW	HIGH	<u>Difference</u>
	<u>R-EST</u>	<u>R-EST</u>		<u>R-EST</u>	<u>R-EST</u>	
Intercept	0.192 (0.072)	0.162 (0.082)		0.086 (0.016)	0.068 (0.004)	
Δ ERN	0.586 (<0.001)	0.932 (<0.001)	-0.346 (0.004)	0.550 (<0.001)	0.874 (<0.001)	-0.325 (0.002)
RSCORE	0.033 (0.021)	0.022 (0.030)		0.031 (0.022)	0.021 (0.028)	
Δ ERN*RSCORE	-0.087 (0.538)	0.161 (0.047)		-0.173 (0.447)	0.137 (0.087)	
R ²	0.076	0.076		0.079	0.085	
Obs.	3,256	25,116		3,256	25,116	

The tables present coefficient estimates and p-values in parentheses of cross-sectional value-relevance regressions with RSCORE (reliability levels) and an interaction of

ΔERN with $RSCORE$. The sample for this analysis includes only profit firms. The regressions are measured separately for profit firms with low number of estimates and profit firms with high number of estimates (LOW EST includes all profit observations recording up to three estimates, while HIGH EST includes all profit observations recording at least four estimates). The model is as follows:

$$RET_t = \alpha + \beta_1 \Delta ERN_t + \beta_2 RSCORE_t + \beta_3 \Delta ERN_t \cdot RSCORE_t + \varepsilon_t \quad (2)$$

Panel A reports results obtained using pooled estimation with firm and year effects and Panel B reports results obtained using Fama-MacBeth estimations (year-by-year).

Definitions of all variables are in Table 1.

Healthy Ecology of Environmental Water and Drinking Water: Integrated Planning and Design

David Benjamin

Abstract— In many countries, particularly in the developed Western European and North American states, environmental waters and drinking water/sewage flows are governed and administered by different laws, regulatory regimes and government departments. This is despite the fact that much drinking water is sourced from the environment, sewage is returned to the habitat sink, legacy and immediate pollutants and bio toxins enter drinking water supplies through the environmental pathway. Thus there is a need to enact overarching, wholistic planning and design that brings together these two realms using the perspective of the FEWW nexus and an integration of the five helices of society's economic sectors. Attempts have been made to engage this work through the source2sea initiative in Europe and the whole watershed planning work of the US Corps of Engineers but has yet to be scaled up to the point where it has necessary and sufficient effects, i.e. witness Flint, Michigan, PFAS sub surface plumes in several regions etc. Nature Based Solutions and ecological engineering as a first choice design with stakeholder engagement may be three viable vehicles for engaging and enacting the needed reforms to this system of governance.

Keywords— wholistic planning, sustainability, circular economy, ecological engineering, stakeholder engagement, source to sea, learning from the past.

The Children's Rights to Independent Status - Three Models for Protecting the Children's Interests in Divorce Proceedings Between Their Parents

Yitshak Cohen

Abstract— The paper examines the right of a minor to independent status in matters of family law, the interests it competes with, and possible new approaches for the future. Legal systems worldwide have expressed concern that parents, while undergoing divorce proceedings and focused on their issues, might compromise the interests of their children. In response to this concern, the courts have allowed re-litigation of prior decisions in divorce proceedings or in written agreements between spouses. What was initially an expression of concern has developed into a legal presumption that parents compromise the interest of minors in divorce proceedings. This shift provides important protection for the interests of the minor. The presumption has been strengthened further by modern values that focus on the rights of the minor. The most practical expression of this development is the accession of the State of Israel to the International Convention of 1989. Moreover, In Israel there is no separation between church and state, and the strengthening of the independent status of the minor enables the civil court to reopen the determinations of the religious court. However, this presumption is supposed to cope with the assumption that parents are natural guardians of their children. Also, the development of the minor's right to independent status has impacted divorce proceedings in several ways, among them: contractual uncertainty, lack of finality of judgment, and prolonged litigation. The paper indicates that in the last decade, the Israeli court went back to the judgments of the sixties and shifted from a substantive standard to a procedural one, for determining the minor's right to re-litigation. The Supreme Court recently accepted this position and reinstated the substantive standard. The paper offers the following three models for protecting the interests of the minor while preserving contractual certainty and the stability of agreements: (i) requiring the court to comprehensively examine the interests of the child and then granting a presumption of validity to the court's determination. That determination should also serve as binding precedent for a subsequent court; (ii) legislating clear considerations and guidelines for defining the best interests of the child and thereby reducing future re-litigation; and (iii) appointing independent representation for the minor. These models may serve to create a more appropriate formula for balancing the competing interests in family law.

Keywords— Best interest of the Child, children's rights, contractual certainty, international convention, protection, relitigating.

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programs, among them Religious Leaders (Christian, Muslim, Druze and Jews) Interfaith LLB Law Program. He was ordained as a rabbi by the Chief Rabbinate of Israel. His primary fields are Jewish law, family law, and civil procedure. He has published four books and numerous articles (e-mail: Itshak_c@ono.ac.il).

Reforming the Law to Allow a Duress Defence to Those Committing Crime under Coercive Control

A. Elkington

Abstract— Women in abusive relationships who commit crimes under duress are unfairly treated by the English legal system. Despite the offence of Coercive Control being introduced in 2015 that recognises that a woman's autonomy has been eroded, coercion is no longer a defence to women who feel compelled to act due to their partner's behaviour or abuse. This problem is intensified by the fact that women in abusive relationships are more likely to commit crimes to ensure their survival. Furthermore, the very fact that they are 'associating' with their abusive partners means that they are excluded from pleading a defence of duress. Women who kill their abusers may be able to reduce their conviction from murder to manslaughter, but this depends on successfully pleading either loss of control or diminished responsibility, both not without their issues, but this does not provide a defence where a lesser crime is committed. Self-defence is also widely unavailable to either murder or non-fatal offences, as the amount of force used is often deemed disproportionate because women are more likely to use weapons in their defence. Regardless, this would not provide a defence where the crime committed is one such as theft. An alternative that has been proposed would be to introduce a new defence that would work similarly to the exemption to prosecution afforded to those who are trafficked that commit crime under duress. Despite having support in the Lords in March 2021, this recommendation has been rejected by the Government on the basis that it would not achieve an appropriate balance of justice. The result is that abused women who commit crime are left without an appropriate defence. A doctrinal approach highlights the injustices in these types of cases and concludes that it time for the current law of duress to change.

Keywords— Coercive Control, Crime, Defences, Duress.

Generation of Health and Its Effect on the Female Labour Market and Economic Development

Shonal Rath

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ABSTRACT:

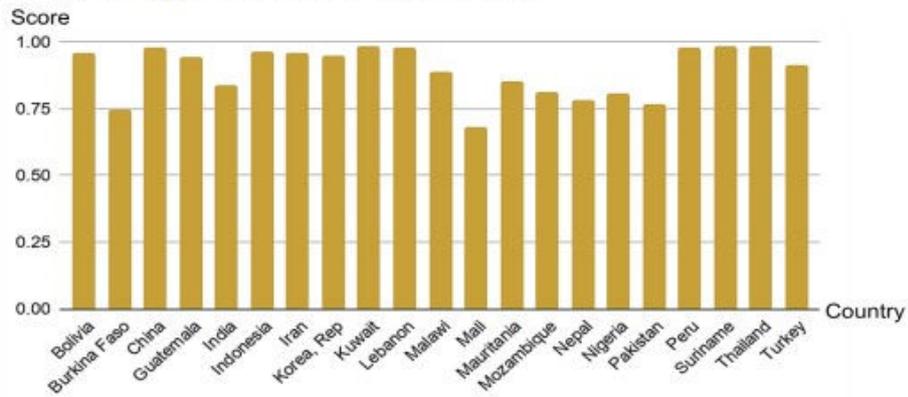
This paper focuses on health as a factor determining the effective labour force of an economy. Health promotes the growth of the economy under full employment conditions in the long run. Long-term health issues stagnate the development of a country by undermining economic growth as well as the wellbeing of individuals. However, access to health is often gender biased. Therefore, this paper provides a theoretical framework where the theory of endogenous growth has been used to discuss how the growth rate of an economy is influenced by health factors in the short-run and long run through female labour employment with the increased access to health resources, thus leading to women empowerment. Finally, a panel data regression analysis has been performed to study the correlation among these variables. This shows that health improvement can serve the two-fold purpose of women economic empowerment and overall development of the economy.

KEYWORDS: female labour supply, education, health, economic growth, endogenous growth, panel data regression.

1. INTRODUCTION

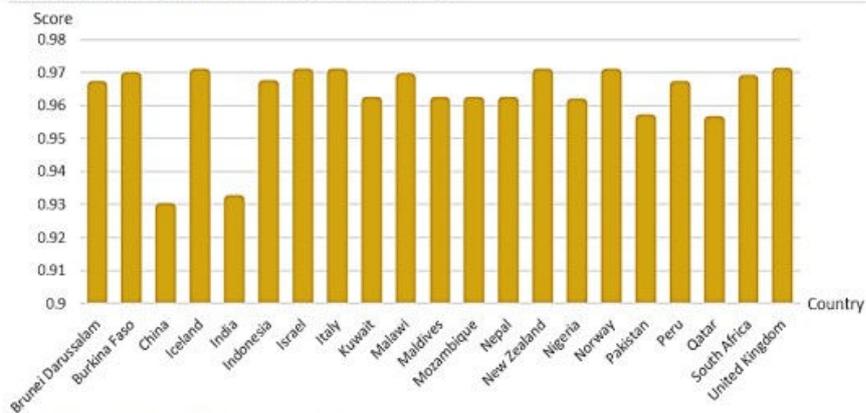
In the modern world with developed countries reaching a superior development phase and developing countries experiencing high growth rates, all the economies need to use their economic resources efficiently. Human capital is one of the most important resources of human civilization which the female population has been historically deprived of. Their low participation prevents the economy from becoming fully functional at an optimum level, thus reducing the output. The assumption of convergence, under the standard neoclassical growth framework, is that a country with a higher human capital 'performs' better than others. So, healthy labour of a sector not only increases the production of goods of that sector through an increase in productivity and knowledge but also boosts the entire production of the economy through the cob-web process. The two most common dimensions of human capital are education and health care services.

Figure 1: Global gender gap educational attainment index



Source: UNDP Global Gender Gap Report

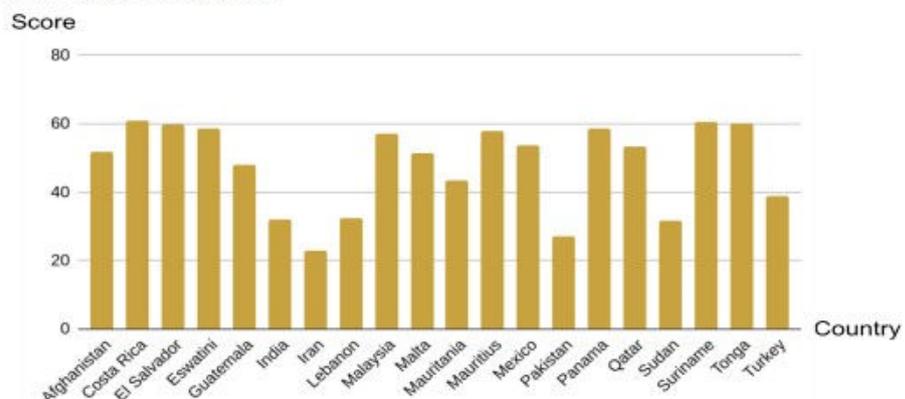
Figure 2: Global gender gap health and survival index



Source: UNDP Global Gender Gap Report

Figures 1 and 2 show the data on the educational attainment index and health index reflecting gender discrimination across countries. This discrimination in access to resources translates to disparity in the participation of the labour force.

Figure 3: Female-male labour ratio



Source: World Bank Open Data

Figure 3 represents the female to male labour force participation ratio which shows that the ratio is below 100 in most cases indicating less involvement of female in the labour force. The reasons for such non-participation pertain to social and political dogma, unpaid care, and health issues which are not addressed. Hence, the prevalent gender gap hinders growth prospects and sustainable growth. The

rest of the paper is structured as follows. Section 2 covers the literature review. Section 3 explains the methodology. Section 4 presents the results.

2. LITERATURE REVIEW:

Mankiw, Romer, and Weil (1992) examined the implications of the augmented Solow model including accumulation of human and physical capital for convergence of standard of living in a cross-country framework. Galor and Weil (1996) found that increasing capital per worker increases women's relative wage. This reduces fertility which in turn raises the capital per work. Chen and Kee (2005) identified education as the major driving force of economic development. They established the link between the growth rate of human capital and the steady-state growth rate of productivity and output per worker. Similarly, Bohórquez et al. (2016) showed a positive relationship between health and labour force participation, especially for females.

Kochar et al. (2016) also showed that the complete involvement of women in the economy is not only growth-promoting but it also diversifies the economies, reduces income inequality and mitigates demographic shifts. We thus provide a theoretical framework to study the effects of health on the growth rate of the economy and female employment. Further, we examine its effect on growth theoretically and then empirically.

3. METHODOLOGY:

We first provide a theoretical model to show the effects of education and health on women empowerment and the growth rate of the economy. Later, these are proved empirically using regression models.

3.1 GROWTH MODEL:

We now present an augmented endogenous growth model to incorporate the effect of female education and health on the growth of an economy and how the inclusion of a skilled female labour force can lead to inclusive growth. Suppose, the production function of the economy is:

$$Y = AK + L_m^\alpha (E(c)L_f)^\beta$$

where,

L_f : female labour force

L_m : male labour force

And other variables include:

A : technology of the economy

K : capital stock of the economy

S : marginal propensity to save

El_f : effective female labour force

E : education level of the females

c : the quality of health service

Proper healthcare can lead educated persons to acquire skills and be involved in the labour force.

The male labour force grows exponentially at a constant rate n .

$$\dot{L}_m/L_m = n$$

Next, we define equations to describe the behaviour of the economy.

$$L_f = cH, c > 0$$

Several empirical studies have focussed on the effects of health on education. Kaestor and Grossman (2009), Case and Paxon (2010), Rees and Sabia (2011) found strong causal links between health and educational attainment and other measures of human capital. Thus, the quality of health care facility will affect educational level E in our model. Again, the level of technology also depends on education, which in turn depends on the quality of healthcare provided, i.e, $A = A(E(c))$

Another reason for such formulation is that the mere injection of unskilled women deprived of proper healthcare in the labour force may increase their share of labour, but this will lead them to receive only low-quality jobs, which will not help them attain a given standard of living. In the long run, low-quality employment will lead to a fall in the share of income of labour.

Next, we describe the generation of H .

$$\dot{H} = \gamma N - \delta_1$$

N : non-participating female labour force

γ : the proportion of n receiving proper healthcare

δ_1 : depreciation in the health level of the people due to other factors

N is given as:

$$N = ae^{\lambda t}$$

Thus, we explicitly consider that at first females get proper health facilities and acquire skills and then they enter the labour force with productive work leading to an increase in their income share and thus overall growth. Herein lies the empowerment of women in our model. The factor γ depends on the amount of public expenditure. The basic reason for such an argument is that with more government spending on female health, more females will be benefited from the public provision of healthcare facilities. In equation (1), EL_f denotes the effective female labour force because education is an important parameter to determine the effectiveness of female labour employed. We first find the value of healthy females per non-participating female labour in the long run.

$$H = \gamma e^{\lambda t} / (\lambda + \delta_1) + c_1 e^{-\delta_1 t}$$

$$(H/N)^* = \gamma / (\lambda + \delta_1)$$

$$L_f = c(\gamma e^{\lambda t} / (\lambda + \delta_1) + c_1 e^{-\delta_1 t})$$

$$(L_f/N)^* = c\gamma / (\lambda + \delta_1)$$

Thus, we have a long-run equilibrium. Next, we proceed with applying the comparative statics in the model.

4. RESULTS AND DISCUSSION

4.1 COMPARATIVE STATISTICS:

4.1.1 Effect of health quality and coverage on the growth rate of capital per male

Productivity of the male labour force increases as male will get more of a different input to work with. Hence, the average product and the marginal product of the male labour force will also increase. This will lead to an increase in male per capita capital stock. Without a healthy female labour force, the only working labour force would have been male with some specific skills. With healthy females taking part in the production, in our model the economy grows endogenously as per capita female labour capital increases

$$Y = AK + L_m^\alpha(E(c)) L_f^\beta$$

$$y = Y/L_m = Ak + sL_m^{\alpha-1}(E(c))L_f^\beta$$

$$y/k = s[A + L_m^{\alpha-1}(E(c)) L_f^\beta k^{-1}]$$

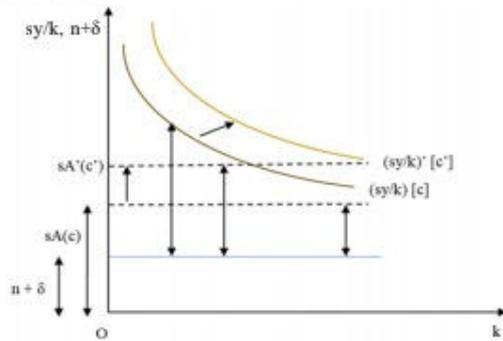
$$\lim_{k \rightarrow \infty} sy/k = sA(E(c))$$

$$\dot{\bar{k}}/\bar{k} = sy/k - (\hat{L} + \delta)$$

\bar{k} : per capita capital

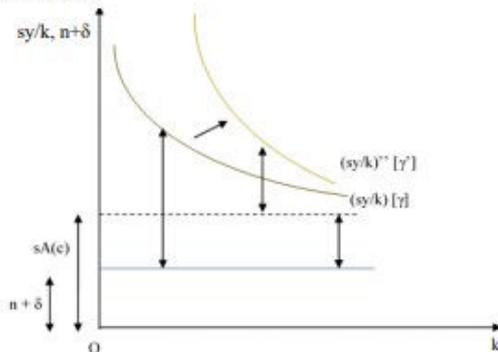
\hat{L} : growth rate of labour

Figure 4: Effect of healthcare quality on capital growth rate



In figure 5, the mm/m curve shifts up as m increases. Improvement in health facilities indicated by a rise in c will lead to a more efficient female labour force with new skills. This will increase the labour force and thus the growth rate of capital per male. Herein lies the essence of the inclusive growth of the economy. As we empower women, it not only increases their income but also augments aggregate income and output. The male labour force is equally benefited from the higher participation of the female in the labour force.

Figure 5: Effect of health coverage on capital growth rate



An increase in γ will also have the same effects as that of an increase in c . Females face several health issues in comparison to males which can be tackled through access to better healthcare facilities. This health improvement will have a positive effect on female employment and output level as well as the per capita case. Results will remain similar qualitatively but differ quantitatively.

4.1.2 Effect of education and health on the growth rate of output

We first derive the long-run growth rate of the economy on the assumptions (refer to the appendix)

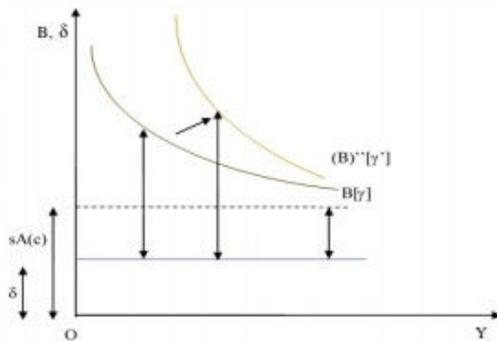
$$Y/Y = sa + (an + \beta\lambda + \delta) [\{ L_m^a(E(c)) L_f^b \} / Y] - \delta$$

$$Y/Y = sA(E(c)) - \delta.$$

An improvement in health parameters will lead to a short-run increase in the growth rate. Better health will increase the productivity of the female labour force as well as the absolute female labour force.

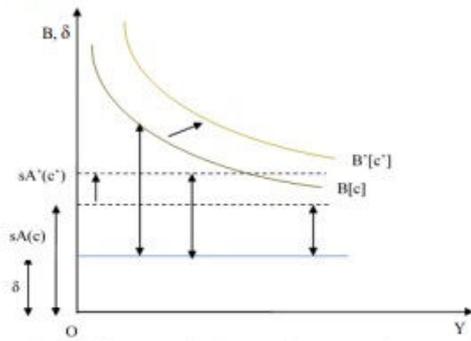
$$B = sA + (an + \beta\lambda + \delta)[\{L_m\alpha(E(c) L_i)\beta\} / Y]$$

Figure 6: Effect of health coverage on output growth rate



But the boost in growth rate won't prevail in the long run. The long-run growth rate will again converge to $sA(E(c))$.

Figure 7: Effect of healthcare quality on output growth rate



The only difference is that an increase in m will be sustained. A rise in c would lead to an increase in A , i.e., technological improvement. Intuitively, an increase in c will lead to an increase in the female labour force which also has its short-run effect. Thus, in the short run, both effects are significant but in the long run, the increase in quality of healthcare of females will be sustained through an increase in education level and thereby technology. This can further be explained to fully justify how females bring about a sustainable growth rate. Some proportion of healthy females only lead to an increase in technology. Thus, in reality, society needs both male and female healthy labourers to have better technology and infrastructure to lead to sustainable growth in the long run.

4.2 EMPIRICAL STUDY:

In this section, we empirically test the propositions made in the growth model and also extend it to further incorporate the effects of labour supply, education and health on certain macroeconomic indicators. Panel data regression: Data for the whole analysis has been collected from World Bank open data, UNDP and IMF Fiscal Affairs Department. We have collected data on 83 countries consisting of developed, developing as well as less developed countries for 11 years (2005-2015). Thus, we have 913 observations in total. We perform the regressions in STATA 13.1.

4.2.1 Regression of female labour force participation rate on education and health parameters

We take the logarithm of the labour force participation rate (ILO modelled) of females which is the proportion of the population who are actively participating in the production process as the dependent variable. Mean schooling years of female is taken as a proxy variable for education level. Three health

parameters are used for independent variables: life expectancy at birth, the adolescent fertility rate (the number of births per 1,000 women aged 15-19) and maternal mortality rate (the number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births). We hypothesize better health empowers women by equipping them with skills to participate in the labour force and thus enabling them to get jobs with higher payrolls.

We justify the simultaneous treatment for the health parameters by the argument that the adolescent fertility rate purely captures the health effects of women during the adolescent period which may hinder their education and also decrease prospects of joining job markets.

This can be explained well in the case of developing and least developed countries where child marriage is still prevalent leading to adolescent pregnancy of female and thus blocking their path towards paid work in the labour market. Maternal mortality rate reflects the death of women while giving births and consequently the state of health care provided, and the technology used. We have estimated the effects of three separate health parameters and education on the log of the female labour participation rate using the random effect model and GLS RE estimators:

$$\begin{aligned} & \text{Log(Female Labour Force Participation Rate)}_{it} \\ &= \alpha + \beta(\text{Mean Schooling Years})_{it} + \delta(\text{Health})_{it} + e_{it} \end{aligned}$$

where we use three proxy variables for health.

The regression results are tabulated in Table 1. Female labour participation rate thus increases as mean schooling year and life expectancy increases in all cases and is statistically significant. However, female labour has a negative relation with both fertility and mortality rate. Thus, we show female labour force participation will increase with improvements in all dimensions of health separately.

Table 1: Regression of female labour force participation rate on education and health parameters

Log(Lf)	(1)	(2)	(3)
Constant	3.760656	3.72571	3.74456
Mean Schooling (years)	0.014935 (0.000)***	0.017164 (0.000)***	0.016397 (0.000)***
Life Expectancy (years)	0.0115 (0.023)**		
Adolescent Fertility Rate (per 1,000 women aged 15-19)		-0.0005357 (0.085)**	
Maternal Mortality Rate (per 100,000 live births)			-0.009105 (0.05)**
R square	0.564	0.654	0.589

*, **, and *** denote significance at 1%, 5%, and 10% respectively.

4.2.2 Regression of GII on education and health parameter

The dependent variable is the Gender Inequality Index (GII) which measures inequality in various aspects of an economy like in education, health, decision making etc. The independent variables are

the mean schooling year and the three health parameters as described earlier. We perform linear regression using GLS RE estimators. We estimate the equation:

$$GII_{it} = \gamma_0 + \gamma_1(Health)_{it} + \gamma_2(Education)_{it} + \varepsilon_{it}$$

We have taken data on 72 countries, including developed, developing, and less developed, for 9 years (from 2005 to 2013). Thus, we have a total of 648 observations. The results of regressing GII are tabulated in Table 2. We found that mean schooling is significant and negatively correlated with GII. An increase in life expectancy and a fall in fertility and mortality rates lead to a fall in gender inequality.

Table 2: Regression analysis of GII on education and health parameters

GII	(1)	(2)	(3)
Constant	0.406984	0.48405	0.3842
Mean Schooling (years)	-0.02644 (0.000)***	-0.01944 (0.000)***	-0.03644 (0.005)***
Life Expectancy (years)	-0.156 (0.000)***		
Adolescent Fertility Rate (per 1,000 women aged 15-19)		0.002157 (0.000)***	
Maternal Mortality Rate (per 100,000 live births)			0.1656 (0.000)***
R square	0.656	0.747	0.756

*, **, and *** denote significance at 1%, 5%, and 10% respectively.

4.2.3 Instrumental variable regression:

We have performed two regressions. In the first case, our dependent variable is the logarithm of real GDP per capita. It measures the per capita real volume of economic activities of the economy in constant 2010 U.S. dollars. In the second case, the dependent variable is the Human Development Index (HDI) which shows the standard of living of a country. The explanatory variables for both cases are female labour force participation rate, mean schooling years of female and three health parameters as described earlier. The two additional independent variables here are the logarithm of the labour force participation rate (ILO modelled) of males which is the proportion of the population who are actively participating in the production process during a specific period and the logarithm of capital stock per capita. We add up the values of general government capital stock and private capital stock constructed based on general government investment flows and private investment flows to obtain the total capital stock expressed in billions of constant 2011 international dollars. Then we divide the total capital stock by the total labour force to obtain the capital per capita. The output is often correlated with the educational attainment and health service of the country which further determines the labour force participation.

Both the female and male labour force participation variables can be correlated with the errors. Thus, we have an endogeneity problem. So, OLS estimates, in this case, may be inconsistent. Hence, we have performed a 2SLS Instrumental Variable Regression using Baltagi (2009) EC2SLS RE estimator to assess the effects of education and health on female labours and thus on GDP by taking education and three health parameters as instrumental variable and log of capital as an independent variable.

Table 3: Descriptive statistics of variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Log(y)	913	8.929468	1.469634	5.787532	11.62597
HDI	913	.7301862	.1574268	.28	.95
Log(Lf)	913	3.897401	.2947299	2.615935	4.461288
Log(Lm)	913	4.357073	.0951927	3.858073	4.569626
Log(k)	913	10.9681	1.092078	7.533463	12.92121
Mean Schooling (years)	913	8.598686	3.474556	.7	13.6
Adolescent Fertility Rate (per 1,000 women aged 15-19)	913	44.99279	42.04108	1.69	211.99
Maternal Mortality Rate (per 100,000 live births)	913	129.7043	210.7572	3	946
Life Expectancy (years)	913	72.3107	8.628578	42.518	83.22927

In both cases of GDP and HDI, we hypothesize a positive relation between dependent variables and all other explanatory variables i.e., female and male labour force participation rate and capital per labour stock. We have the female labour force as an endogenous variable determined by education and health parameters. We have performed the regression analysis for each dependent variable three times taking separately the three different proxies for health variables and mean schooling years as a proxy for education variables. a) First, we show the regression analysis for GDP as the dependent variable using the equations:

$$\text{Log}(y)_i = a_0 + a_1 \log(L_f)_i + a_2 \log(L_m)_i + a_3 \log(k)_i + \varepsilon_i$$

$$\text{Log}(L_f)_i = \beta_0 + \beta_1(\text{Health})_i + \beta_2(\text{Education})_i + \varepsilon'_i$$

where,

y : GDP per capita

L_f : Female labour participation rate

L_m : Male labour participation rate

k : Capital stock per capita

Table 4 shows the regression results using the EC2SLS RE method. Here we have used (1) adolescent fertility, (2) mortality and (3) life expectancy as the proxy variable for health. We find that both the labours and capital are positively related to GDP which are statistically significant in all three cases. We also find females have a higher output elasticity than male in all cases. Now considering the elasticities, if we increase all inputs by 1 unit, then GDP rises by more than 1 unit implying the fact the production function exhibits Increasing Return to Scale (IRS) in presence of quality health and education

Table 4: Regression results using the EC2SLS RE method

Log(y)	(1)	(2)	(3)
Log(Lf)	1.847314 (0.000)***	1.675575 (0.000)***	1.691644 (0.000)***
Log(Lm)	0.8435 (0.003)***	0.64503 (0.023)**	0.6719 (0.002)***
Log(k)	0.684808 (0.000)***	0.72678 (0.000)***	0.71704 (0.000)***
Constant	-2.10609	-2.76188	-2.6006
R square	0.611	0.698	0.687

*, **, and *** denote significance at 1%, 5%, and 10% respectively.

Next, we estimate the following equations:

$$HDI_{it} = a_0 + a_1 \log(L_f)_{it} + a_2 \log(L_m)_{it} + a_3 \log(k)_{it} + \varepsilon_{it}$$

$$\log(L_f)_{it} = \beta_0 + \beta_1 (Health)_{it} + \beta_2 (Education)_{it} + \varepsilon'_{it}$$

We find a similar result here as well. Both the labours and capital are positively related to HDI which are statistically significant in the above three cases. Here also, females have a higher output elasticity than male in all cases. Thus, we find that an increase in female labour augmented by better health and education uplifts the standard of living. Herein lies the essence of women empowerment

Table 5: Regression results of HDI on labour and capital

HDI	(1)	(2)	(3)
Log(Lf)	0.61544 (0.000)***	0.391832 (0.000)***	0.493007 (0.000)***
Log(Lm)	0.49674 (0.000)***	0.3087 (0.000)***	0.39624 (0.000)***
Log(k)	0.117292 (0.000)***	0.122422 (0.000)***	0.123133 (0.000)***
Constant	-0.79055	-0.79464	-0.81533
R square	0.645	0.625	0.651

*, **, and *** denote significance at 1%, 5%, and 10% respectively.

5. CONCLUSION:

Government and policymakers should improve the basic education and healthcare facilities to increase female labour force participation. This increases the overall level of output and reduces the gender gap in society, thereby leading to the sustainable growth of the economy. Apart from this, emphasis should be on reducing the Adolescent Fertility Rate (AFR) to ensure that females belonging to the age group from 15 to 19 years can solely focus on education and prospects of their life. Thus, it can be concluded that education and health services are key factors in empowering women. Such

reforms benefit both male and female as we proceed towards a more equitable world with healthy and educated citizens across countries.

REFERENCES:

1. Baltagi, B. H. (2009). *A Companion to Econometric Analysis of Panel Data*. Chichester, UK: Wiley
2. Case, A., & Paxson, C. (2010). *The long reach of childhood health and circumstance: Evidence from the Whitehall II study*. Working Paper 15640, National Bureau of Economic Research.
3. Erdem, E., Yücel, A. G., & Köseoğlu, A. (2016). *Female labour force participation and economic growth: theoretical and empirical evidence*. *The Empirical Economics Letters*, 15(10), 985-991.
4. Galor, O., & Weil, D. (1996). *The Gender Gap, Fertility, and Growth*. *The American Economic Review*, 86(3), 374-387. Retrieved from <http://www.jstor.org/stable/2118202>
5. International Monetary Fund.(2020). Indicators M F 2013-2020 [Data set]. Retrieved from <https://www.imf.org/en/Data> accessed on 24th September, 2020
6. Iregui-Bohórquez, A. M., Melo-Becerra, L. A., & Ramírez-Giraldo, M. T. (2016). *Health status and labor force participation: evidence for urban low and middle income individuals in Colombia*. *Portuguese Economic Journal*, 15(1), 33-55. <https://doi.org/10.1007/s10258-016-0116-7>
7. Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*. 107(2), 407-437. <https://doi.org/10.3386/w3541>.
8. Rees, D. I., & Sabia, J. J. (2011). *The effect of migraine headache on educational attainment*. *The Journal of Human Resources*, 46(2), 317–332.
9. United Nations Development Programme. Human Development Reports. Retrieved from <http://hdr.undp.org/en/data> accessed on 24th September, 2020
10. World Bank. (2020). World Development Indicators 2013-2020 [Data set]. Retrieved from <https://data.worldbank.org>

APPENDIX

$$E = aye\lambda t / (\lambda + \delta_1) + c_1 e^{-\delta_1 t} \quad \text{where } t \rightarrow \infty$$

$$(E/N)^* = \gamma / (\lambda + \delta_1)$$

$$L_F = c [\alpha \gamma e^{\delta_1 t} / (\lambda + \delta_1) + c_1 e^{-\delta_1 t}]$$

$$(L_F/N)^* = c \gamma / (\lambda + \delta_1)$$

$$K = kL_M$$

$$\dot{K} = \dot{k}L_M + k\dot{L}_M$$

$$sY - \delta K = \dot{k}L_M + k\dot{L}_M$$

$$\dot{k}/k = sy/k - (n + \delta)$$

$$K = \tilde{k}\tilde{L}$$

$$\dot{K} = \dot{\tilde{k}}\tilde{L} + \tilde{k}\dot{\tilde{L}}$$

$$sY - \delta \tilde{k} = \dot{\tilde{k}}\tilde{L} + \tilde{k}\dot{\tilde{L}}$$

$$\dot{\tilde{k}}/\tilde{k} = sy/k - (\tilde{L} + \delta)$$

$$Y = AK + L_M \alpha (HL_F) \beta$$

$$\dot{Y} = A\dot{K} + \alpha L_M \dot{\alpha} - (HL_F) \beta \dot{L}_M + \beta HL_M \alpha (HL_F) \beta - \dot{L}_F$$

$$\dot{Y} = A(sY - \delta K) + L_M \alpha (HL_F) \beta [\alpha \dot{L}_M / L_M + \beta \dot{L}_F / L_F]$$

$$\dot{Y}/Y = sA - A\delta K/Y + L_M \alpha (HL_F) \beta (\alpha n + \beta \lambda) / Y$$

$$\dot{Y}/Y = sA + L_M \alpha (HL_F) \beta (\alpha n + \beta \lambda + \delta) / Y - \delta$$

Destiny of Dissent: Democratic Deliberation in the State of Exception

Garrett Jones

Abstract— Carl Schmitt’s Critique of liberal constitutionalism strikes at the essence of democratic politics. This paper defends the capacity of liberal constitutionalism by arguing its ability to balance both effectiveness and accountability in response to emergencies. In crises, rather than rely on deliberation, prediction, and rationality, Schmitt insists on the power of swift decision, intuition, and action. In other words, Schmitt argues the preservation of society ought to be guided by the transformation of ‘ratio’ (reason), back into the hands of ‘voluntas’ (power). The challenge for liberal constitutionalism, therefore, is threefold. First, as Carl Schmitt emphatically argues, the executive must be sufficiently empowered to handle crises. Second, the executive ought to have a duty as a steward of the office to preserve constitutional values through necessary use of prerogative. Thirdly, the public ought to be involved in using its rationality to judge executive discretion. Through their reason, in unison with other institutional spheres of power, the public draws a distinction between necessary and arbitrary executive actions.

Keywords— exception, prerogative, democratic deliberation, constitutionalism.

Joint Physical Custody: Lessons from the European Union

K. Kamińska

Abstract—When thinking about custodial arrangements after divorce or separation, there has been a shift from sole custody, particularly maternal preference, to joint physical custody. In many Western countries, an increasing of children with separated parents have joint physical custody which is believed to be in the best interests of the child, as children can maintain personal relations and direct contact with both parents on a regular basis. The aim of the article is to examine joint physical custody, both from the perspective of the binding legal instruments that are relevant to joint physical custody, the Principles of European Family Law drafted by the CEFL, as well as the international research on this matter. The thesis underlying this paper is that joint physical custody is in itself neither good nor bad, and it depends on how the arrangements are managed by the parents. The paper includes a reflection on joint physical custody in the face of the COVID-19 crisis. The results indicate that in normal circumstances joint physical custody demands broad communication and now it times of crisis, we need over-communication about children and plans. Only a very tight and coordinated co-parenting plan make the whole family safer.

Keywords—joint physical custody, co-parenting, COVID-19, child welfare.

China and the Criminalization of Aggression. The Juxtaposition of Justice and the Maintenance of International Peace and Security

Elisabetta Baldassini

Abstract— Responses to atrocities are always unique and context-dependent. They cannot be foretold nor easily prompted. However, the events of the twentieth century had set the scene for the international community to explore new and more robust systems in response to war atrocities, with the ultimate goal being the restoration and maintenance of peace and security. The outlawry of war and the attribution of individual liability for international crimes were two major landmarks that set the roots for the development of international criminal law. From the London Conference (1945) for the establishment of the first international military tribunal in Nuremberg to Rome at the inauguration of the first permanent international criminal court, the development of international criminal law has shaped in itself a fluctuating degree of tensions between justice and maintenance of international peace and security, the cardinal dichotomy of this article. The adoption of judicial measures to achieve peace indeed set justice as an essential feature at the heart of the new international system. Blackhole of this dichotomy is the crime of aggression. Aggression was at first the key component of a wide body of peace projects prosecuted under the charges of crimes against peace. However, the wide array of controversies around aggression mostly related to its definition, determination and the involvement of the Security Council silenced, partly, a degree of efforts and agreements. Notwithstanding the establishment of the International Criminal Court (ICC), jurisdiction over the crime of aggression was suspended until an agreement over the definition and the conditions for the Court's exercise of jurisdiction was reached. Compromised over the crime was achieved in Kampala in 2010 and the Court's jurisdiction over the crime of aggression was eventually activated on 17 July 2018. China has steadily supported the advancement of international criminal justice together with the establishment of a permanent international judicial body to prosecute grave crimes and has proactively participated at the various stages of the codification and development of the crime of aggression. However, China has also expressed systematic reservations and setbacks. With the use of primary and secondary sources, including semi-structured interviews, this research aims at analyzing the role that China has played throughout the substantive historical development of the crime of aggression, demonstrating a sharp inclination in the maintenance of international peace and security. Such state behavior seems to reflect national and international political mechanisms that gravitate around a distinct rationale that involves a share of culture and tradition.

Keywords— maintenance of peace and security, cultural expression of justice, crime of aggression, China.

Dual Citizenship Challenges in Zimbabwe: High Court v. Supreme Court Rulings

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ABSTRACT

Descendants of migrant laborers living in Zimbabwe were rendered stateless due to the Zimbabwean government's interpretation of its citizenship laws that banned dual citizenship. Individuals with ties to foreign countries were blocked from accessing their Zimbabwean citizenship on the grounds that they must first renounce their potential claim to a foreign citizenship. Between 2000 and 2006, an era in which judicialization literature proliferated, Zimbabwean courts were inundated with legal challenges to the government's interpretation of its dual citizenship laws. After reviewing High Court and Supreme Court decisions, I found that the High Court continuously ruled in a way that protected citizenship rights. However, I also found that the High Court's attempts to protect individuals' citizenship rights were largely unsuccessful. I explain this with three reasons: the conflicting Supreme Court judgment handed down in *Registrar General of Citizenship v. Todd*, the Registrar General's refusal to comply with the High Court's rulings, and the failure of the legislature to synchronize dual citizenship laws with the 2013 constitution until 2019. My findings indicate that the High Court of Zimbabwe was able to retain some independence in Mugabe-era Zimbabwe, despite that it was purged and packed with Mugabe loyalists.

INTRODUCTION

When Zimbabwe was under British colonial rule, its government relied on unskilled foreign labor from Malawi, Zambia, and Mozambique to operate farms and mines. Mugabe-era laws rendered stateless individuals with the potential to claim a foreign citizenship, who were often descendants of colonial-era farm workers. Today, 300,000 descendants of migrant workers are at risk of statelessness in Zimbabwe.¹ These laws were thought to have targeted white settlers, but they caused the greatest harm to descendants of migrant workers from neighboring African states. The High Court of Zimbabwe's attempts to undo former President Robert Mugabe's politicization of dual citizenship law were largely unsuccessful because of a conflicting Supreme Court judgment, the Registrar General's refusal to comply with the High Court's rulings, and the failure of the Zimbabwean legislature to synchronize dual citizenship laws with the 2013 constitution until 2019.

¹ Amnesty International, *We are like Stray Animals: Thousands Living on the Margins due to Statelessness in Zimbabwe*, 2021, 5.

Dual citizenship, as a political issue that swept through the Zimbabwean judiciary, reflects a broader trend of judicialization, in which courts are increasingly deciding political questions. Ran Hirschl contended that there is a worldwide trend of the judicialization of "mega-politics" because supreme courts are increasingly answering questions of an "outright political nature and significance."² Mega-politics includes issues of "collective identity and nation-building," which Hirschl perceived to be "the most troubling" manifestation of judicialization.³ The dual citizenship cases brought before the High Court and Supreme Court of Zimbabwe fit into the category of collective identity and nation-building because the cases sought to define who was and who was not Zimbabwean. In Zimbabwe, it has not only been the Supreme Court, but the High Court too, that answered questions of national identity. However, because the Supreme Court was the final court of appeal until the adoption of the 2013 Constitution, it overturned one of the High Court's decisions that expanded dual citizenship rights. Therefore, the hierarchical structure of the judiciary meant that the High Court ruled in a way that protected citizenship rights while the Supreme Court felt pressured to rule in a way that was consistent with the politics of the era.

Further, judicialization can occur when a government seeks to "centralize its control, reduce judicial accountability, or curtail citizens' rights."⁴ Zimbabwe's politicization of dual citizenship met these prerequisites of judicialization. When President Robert Mugabe felt that his power was threatened ahead of the 2002 presidential election, he purged and packed the High Court and Supreme Court with loyalists, thereby reducing judicial accountability. Citizens' rights were curtailed when the Supreme Court agreed with the government's position that those with the mere potential claim to a foreign citizenship must renounce it in order to remain a citizen of Zimbabwe.

BACKGROUND

Citizenship in Zimbabwe is particularly politically salient because of Zimbabwe's settler-colonial past. During the colonial era, under the Southern Rhodesia Citizenship and British Nationality Act of 1949, the British allowed dual citizenship to accommodate white settlers.⁵ Contrastingly, Black Zimbabweans were designated as second-class citizens, only to be defined as "British subjects" who lacked full citizenship rights.⁶ In 1965, Rhodesian Prime Minister Ian Smith adopted the Unilateral Declaration of Independence to create a white-minority government independent of Britain. The violent Zimbabwean War for Liberation ensued. Under the Smith government, dual citizenship was permitted. Because the regime was under international sanction, the Rhodesian economy depended on traders with multiple nationalities who traveled on foreign passports. Rhodesian-issued passports were not recognized by other states who perceived the white-minority government as illegitimate.⁷

² Ran Hirschl, "The Judicialization of Politics," *The Oxford Handbook of Political Science* (2011): 1.

³ Ran Hirschl, "The Judicialization of Mega-Politics and the Rise of Political Courts," *The Annual Review of Political Science* (2008): 98.

⁴ Tabath Masengu, "The Vulnerability of Judges in Southern Africa: Alarming Trends," *Africa Today* 63, 4 (Summer 2017): 6.

⁵ J. L. Fisher, "Decolonising Settler Citizenship: The Decolonisation of White Identity in Zimbabwe," in *Pioneers, Settlers, Aliens, Exiles* (Canberra, Australia: The Australian National University, 2010), 129.

⁶ *Ibid*, 107.

⁷ Musiwaro Ndakaripa, "The State and Contested Citizenship in Zimbabwe, 1980-2011" in *Nationalism and National Projects on Southern Africa* (Pretoria, South Africa: Africa Institute of South Africa, 2013), 296.

After the war, the British imposed the Lancaster Constitution upon Zimbabwe.⁸ Therefore, the independence constitution continued the British precedent of permitting dual citizenship.⁹ In 1983, the constitution was amended to prohibit dual citizenship because the ruling Zimbabwe African National Unity-Patriotic Front (ZANU-PF) argued that holders of dual citizenship and expatriate workers were "promoting foreign political and economic interests."¹⁰ Those who possessed dual citizenship were labeled "half-hearted citizens," meaning that they had split loyalties.¹¹ The Mugabe government believed that dual citizenship would inhibit the formation of a Zimbabwean identity and that dual citizenship existed to appease non-indigenous Zimbabweans, particularly the land-owning white settlers who owned 70 percent of arable land at independence.¹²

In 1984, the Mugabe government adopted the Citizenship of Zimbabwe Act, which provided that Zimbabwean citizens with dual citizenship must declare, within one year, that they had renounced their other citizenship.¹³ The Act did not mention individuals who lacked dual citizenship but retained the potential to claim a foreign citizenship. Individuals who failed to renounce their foreign citizenship would automatically lose their Zimbabwean citizenship.¹⁴ However, there was no requirement that individuals show proof from the foreign country that they had renounced their foreign citizenship.¹⁵ Additionally, these individuals, labeled 'aliens,' retained the enfranchisement that they held since 1980.¹⁶ The ZANU-PF had enjoyed the support of migrant workers and their descendants until the emergence of the opposition party, the Movement for Democratic Change (MDC), in late 1999.¹⁷

The crackdown on dual citizenship was perceived as an attack against the remaining white settlers. The Zimbabwean government warned white settlers that they would be stripped of their Zimbabwean citizenship if they "could not produce foreign documentation showing they had no entitlement to the citizenship of another country."¹⁸ The government hoped to disenfranchise approximately 30,000 white settlers, but this policy had a disproportionate effect on the descendants of Malawian, Mozambican, and Zambian migrants.¹⁹ The law was interpreted in such a way that those with the potential to claim a foreign citizenship, i.e. descendants of migrant workers and white settlers, must also renounce their claim to a foreign citizenship. However, foreign governments would not let individuals renounce a mere potential claim to citizenship. Second, third, and fourth-generation Malawian migrant workers, for example, could not renounce

⁸ John Hatchard, "The Constitution of Zimbabwe: Towards a Model for Africa?" *Journal of African Law* 35, 1/2 (1991): 79.

⁹ Bronwen Manby, "Report on Citizenship Law in Zimbabwe," *European University Institute: Robert Schuman Centre for Advanced Studies* (January 2019): 4.

¹⁰ Ndakaripa, 294.

¹¹ Anusa Daimon, "ZANU (PF)'s Manipulation of the 'Alien' Vote in Zimbabwean Elections: 1980-2013," *South African Historical Journal* 68, 1 (2016): 117.

¹² Ndakaripa, 299; Mahove, Christopher. "Mugabe's Demise Brings Hope to Zimbabwe's Ousted White Farmers." *Reuters* (January 30, 2018).

¹³ Citizenship of Zimbabwe Act, Section 9(8).

¹⁴ Manby, "Report on Citizenship Law in Zimbabwe," 5.

¹⁵ *Ibid*, 5.

¹⁶ Daimon, "ZANU (PF)'s Manipulation of the 'Alien' Vote in Zimbabwean Elections: 1980-2013," 116.

¹⁷ Anusa Daimon, "Politics of Othering and the Struggle for Citizenship in Independent Zimbabwe: Voices from Malawian Descendants," *Africa Insight* 44, 1 (June 2014): 142.

¹⁸ Bronwen Manby, "Natives and Settlers," in *Struggles for Citizenship in Africa* (London, United Kingdom: Zed Books, 2011), 43.

¹⁹ Daimon, "Politics of Othering and the Struggle for Citizenship in Independent Zimbabwe: Voices from Malawian Descendants," 142.

Malawian citizenship because they had no claim to it; under Malawian citizenship laws, anyone who left Malawi for another country automatically lost their citizenship at age twenty-one.²⁰ Many descendants of migrant workers were therefore rendered stateless, as the Zimbabwean government still stripped citizenship from those who were unable to renounce their alleged claim to a foreign citizenship.

Following the adoption of the Citizenship Act, Registrar General Tobaiwa Mudede and his office refused to renew the Zimbabwean passports of dual nationals and also those with the potential claim to a foreign citizenship, arguing that those denied must first renounce any entitlement to foreign nationality in accordance to the laws of the foreign state.²¹ This was inconsistent with the 1984 Citizenship Act in two ways. Firstly, the Citizenship Act did not require individuals with the mere entitlement to foreign citizenship to renounce it, only individuals who actually possessed dual citizenship were required to renounce it. Secondly, the 1984 Citizenship Act did not require individuals to renounce their citizenship in accordance with the laws of a foreign country, only in accordance with domestic Zimbabwean law. This was particularly detrimental to individuals born in Zimbabwe of foreign descent, who numbered 1.5 million at the time of the Citizenship Act's promulgation.²² The Supreme Court cases of *Carr v. Registrar General* and *Purser v. Registrar General* challenged the Registrar General's interpretation of the Citizenship Act.

THE JUDICIARY

In the 2000 case of *Carr v. Registrar General*, the Registrar General refused to renew the citizenship of Robyn Carr, who was of British descent.²³ Her application was rejected on the grounds that she must first prove renunciation of her British citizenship under British law.²⁴ The Supreme Court ordered that her passport be renewed because she had complied with the renunciation of foreign citizenship.²⁵ Further, the Court argued that the Registrar General lacked the power to require Carr to renounce her citizenship under British law because the law did not require proof of renunciation of foreign citizenship.²⁶ Similarly, in the 2001 Supreme Court case of *Purser v. Registrar General*, the Supreme Court followed its precedent set in *Carr* and ruled that Sterling Purser was entitled to a Zimbabwean passport.²⁷ Purser, who was born in Zimbabwe to a British father, had been denied a passport on the grounds that he had not renounced his entitlement to foreign citizenship.²⁸ Because the 1984 Citizenship Act did not address individuals with only the entitlement to foreign citizenship, Purser, who did not possess dual citizenship, could not be required to renounce it.

In 2001, following the *Carr* and *Purser* decisions, the Mugabe government amended the Citizenship Act to require renunciation of dual citizenship under the relevant foreign law, not only

²⁰ Amnesty International, 13.

²¹ Manby, "Natives and Settlers," 44.

²² Daimon, "Politics of Othering and the Struggle for Citizenship in Independent Zimbabwe: Voices from Malawian Descendants," 123.

²³ *Carr v. Registrar-General*, 2000 (2) ZLR 433 (S).

²⁴ *Ibid.*

²⁵ *Ibid.*

²⁶ Manby, "Natives and Settlers," 43.

²⁷ *Ibid.*, 43.

²⁸ *Ibid.*, 43.

under Zimbabwean law, which was the case since 1984.²⁹ The British government announced that it did not recognize Zimbabwe's law requiring the renunciation of foreign citizenship.³⁰ Thus, individuals who had technically renounced British citizenship still remained British citizens in practice.³¹ Therefore, the amendment was a mechanism adopted by the Zimbabwe government in response to the *Carr* and *Purser* decisions, and also to British noncompliance. There was some publicity of the amendment in urban areas, but many affected rural-dwellers remained uninformed until the deadline passed and their Zimbabwean citizenship had been stripped.³² The amendment rendered stateless between 100,000 and 200,000 African migrants and their descendants.³³ Further, the amendment followed the 2000 parliamentary election, which was the first election in which Mugabe faced serious opposition.³⁴ The opposition party, the Movement for Democratic Change (MDC), had won fifty-seven parliamentary seats and the ZANU-PF, sixty-two.³⁵

After the ZANU-PF's marginal victory in the parliamentary election, Mugabe felt that his power was threatened ahead of the 2002 presidential election.³⁶ This prompted his decision to disenfranchise a key swing vote: 'alien' farm workers of Malawian, Mozambican, and Zambian descent.³⁷ Mugabe argued that the descendants of migrant workers, the 'aliens' with the potential to claim a foreign citizenship, were to blame for his declining support.³⁸ Mugabe believed that white farmers funded the formation of the MDC and farm workers extended their support to the opposition party.³⁹ Thus, the government saw Black Zimbabweans who supported the MDC opposition as "sell-outs, traitors, and puppets of the West."⁴⁰ Under the new amendment to the Citizenship Act, dual citizens had to prove renunciation of their foreign citizenship by proof provided by the foreign government.⁴¹ If individuals failed to show proof from the respective foreign government in six months, they were automatically stripped of their Zimbabwean citizenship.⁴² The short deadline was provided in hope that white settlers and farm workers of foreign descent would be disenfranchised before the 2002 election.⁴³

Further, the party believed it would be unable to implement its land reform program if interfering foreign interests were able to permeate Zimbabwean society via white settlers and farm workers of foreign descent who possessed Zimbabwean citizenship.⁴⁴ There was thus a political motivation

²⁹ Citizenship of Zimbabwe Act, Section 9, as amended Act No. 12 of 2001.

³⁰ Ndakaripa, 306.

³¹ *Ibid*, 306.

³² Manby, "Natives and Settlers," 45.

³³ Lawyers for Human Rights, *Statelessness and Nationality in South Africa*, 2011, 19.

³⁴ Peter Alexander, "Zimbabwean Workers, the MDC & the 2000 Election," *Review of African Political Economy* 85 (February 2007): 385.

³⁵ Norma J. Kriger, "Robert Mugabe, Another Long Too-Serving African Ruler: A Review Essay," *Political Science Quarterly* 118, 2 (2003): 309.

³⁶ Daimon, "ZANU (PF)'s Manipulation of the 'Alien' Vote in Zimbabwean Elections: 1980-2013," 118.

³⁷ Clement Chipenda, "Land Reform, Citizenship, and Aliens in Zimbabwe," *Africa Review* 13, 1 (February 2021): 17.

³⁸ "Zimbabwe Premier's Office Working on Proposal to Change Citizenship Laws," *BBC Monitoring Africa* (London, United Kingdom: SW Radio Africa, August 20, 2009).

³⁹ Alois S. Mlambo, "Becoming Zimbabwe or Becoming Zimbabwean: Identity, Nationalism, and State-Building," *Africa Spectrum* 48, 1 (2013): 61.

⁴⁰ *Ibid*, 50.

⁴¹ Citizenship of Zimbabwe Act, section 9, as amended Act No. 12 of 2001.

⁴² Lawyers for Human Rights, *Statelessness and Nationality in South Africa*, 2011, 19.

⁴³ Daimon, "ZANU (PF)'s Manipulation of the 'Alien' Vote in Zimbabwean Elections: 1980-2013," 123.

⁴⁴ Ndakaripa, 294.

to abolish dual citizenship to ensure full civilian loyalty to the 2002 Land Acquisition Act, which redistributed white-owned land to Black Zimbabweans.⁴⁵ The Mugabe government perceived migrant workers and their descendants as loyal to the white settlers who employed them and, by default, as also opposing the Land Acquisition Act.⁴⁶ Additionally, only indigenous Zimbabweans were supposed to benefit from the land redistribution program.⁴⁷ Therefore, Zimbabweans of foreign ancestry were denationalized to prevent them from obtaining Zimbabwe's land.

Ahead of the 2002 election, President Robert Mugabe strategically launched his judicial purges. Independent judges were pressured to resign and Mugabe sympathizers were appointed to both the High Court and the Supreme Court.⁴⁸ Chief Justice Anthony Gubbay was forced to retire and was replaced by former Deputy Minister of Justice Godfrey Chidyausiku, a supporter of the ZANU-PF and a proponent of the Land Acquisition Act, in March 2001.⁴⁹ Five days before Justice Gubbay was forced off the bench, the Supreme Court had struck down Mugabe's attempt to nullify the MDC's petitions against results in the 2000 parliamentary election.⁵⁰ The MDC filed petitions that the election had been rigged in thirteen constituencies that the ZANU-PF had won.⁵¹ After Chief Justice Gubbay was replaced, Justice Simbarashe Mucsheteere died and Justice Nicholas McNally retired after reaching the mandatory retirement age.⁵² Both Justice Mucsheteere and Justice McNally had challenged the Mugabe government, so their losses further impeded the independence of the Zimbabwean Supreme Court. Justice Mucsheteere had pushed back on the Mugabe government's human rights abuses and the white, South African-born Justice McNally had ruled against Mugabe's land reform program.⁵³

On July 27, 2001, Mugabe's government announced that it was expanding the size of the Supreme Court from five justices to eight, and in August, Misheck Cheda, Vernanda Ziyambi, and Luke Malaba took the bench.⁵⁴ The opposition described the expanded court as a mechanism for the government to extend its influence over the judiciary, as the new appointees were described as "sympathetic to the Mugabe regime."⁵⁵ The opposition argued that the "real reason" for the enlarged Supreme Court was to "ZANU-ize" the judiciary, while the ZANU-PF maintained that the expanded Supreme Court was designed to decrease the caseload for the justices.⁵⁶ Further, the ZANU-PF masked itself behind the shield of legality. The expansion of the Supreme Court was consistent with the 1980 Constitution, which did not provide for a specific number of justices and instead provided that the court would be headed by the Chief Justice and joined by at least two

⁴⁵ *Ibid*, 294.

⁴⁶ Chipenda, 3.

⁴⁷ *Ibid*, 16.

⁴⁸ Justice Anthony R. Gubbay, "The progressive Erosion of the Rule in Zimbabwe," from the *Third International Rule of Law Lecture: Bar of England and Wales* (December 9, 2009): 2.

⁴⁹ Bureau of African Affairs, "Loss of Two Zimbabwe Supreme Court Justices Strengthens ZANU-PF's Influence Over Bench," Wikileaks Cable: 02HARARE38_a, dated January 4, 2002; "Mugabe Appoints his Judges," *News24*, (July 27, 2001).

⁵⁰ Legal Resources Foundation, 10.

⁵¹ "Zimbabwe's Opposition Party Files Petitions Against Poll Results." *Xinhua* (April 20, 2005).

⁵² Bureau of African Affairs, 2002.

⁵³ "Mugabe Demands Zimbabwean Judges Quit President Bristles at Criticism of Human-Rights Record after Journalists Say they were Tortured." *The Globe and Mail, Toronto* (February 8, 1999); "Retired Supreme Court Justice Nicholas McNally Dies." *Zimbabwe Situation* (January 25, 2021).

⁵⁴ "Mugabe Appoints Three New Judges," *The New Humanitarian* (July 27, 2001).

⁵⁵ *Ibid*; "Zimbabwe Leader Swears in Three Supreme Court Judges," *BBC Monitoring Newsfile, London* (August 2, 2001).

⁵⁶ "Mugabe Accused of Nominating Sympathetic Judges," *Breaking News, Cork* (July 27, 2001).

other justices.⁵⁷ The Constitution, therefore, gave the president the power to expand the number of justices as he or she wished.⁵⁸

The Supreme Court justices and High Court judges were themselves challenged by the dual citizenship disputes that they sought to address in their rulings. In 2000, a year before the judicial purges and packing began, two of the five supreme court judges were white, including Chief Justice Anthony Gubbay, and four of the twenty High Court judges.⁵⁹ The government claimed that Justice Gubbay had not properly renounced his claim to British citizenship, and therefore was not a Zimbabwean citizen.⁶⁰ Similarly, the government told High Court Judge Micheal Gillespie that he was not a Zimbabwean citizen because of his British ties.⁶¹

On the High Court, ten judges resigned in protest of the regime or after facing intimidation.⁶² The government had criticized them for their rulings in "politically sensitive cases."⁶³ While the High Court judges were replaced by individuals thought to be Mugabe sympathizers, some displayed independence.⁶⁴ The High Court's ability to retain some independence in Mugabe-era Zimbabwe can be observed by comparing the High Court's rulings on questions of dual citizenship to Supreme Court decisions following the judicial purges. Before the new Constitution of Zimbabwe was adopted in 2013, the Supreme Court was the highest in the country. As the final court of appeal, its decisions were final, increasing the political salience of its rulings compared to the High Court, the court beneath it. This can help explain why the High Court, despite also being packed with Mugabe supporters, was able to maintain some independence. Judges on the High Court felt less political pressure to rule in favor of the Mugabe government on issues of dual citizenship because their rulings could be appealed and overturned in the Supreme Court.

COURT CASES

In 2002, the High Court ruled in *Tsvangirai v. Registrar General of Elections* that it could not be assumed that a person had a right to foreign citizenship only because his or her parents were born elsewhere.⁶⁵ Further, it held that a person could not be required to renounce what he or she never possessed.⁶⁶ Morgan Tsvangirai, the MDC presidential candidate, brought the case to the High Court because he sought an extension of the deadline to renounce foreign citizenship. He wanted to ensure that more MDC supporters were able to vote. The Court extended this deadline from January 6, 2002 to August 6, after the March presidential election.⁶⁷ The Registrar General appealed the decision a month before the election to the recently-packed Supreme Court, in *Registrar General & Ors v. Tsvangirai*, which overturned the High Court's decision.⁶⁸ During

⁵⁷ Constitution of Zimbabwe, 1980, Section 80(2)(b).

⁵⁸ *Ibid*, Section 80(2)(b).

⁵⁹ "Mugabe Regime Prepares to Axe White Judges," *The Guardian* (June 4, 2000).

⁶⁰ *Ibid*.

⁶¹ *Ibid*.

⁶² Legal Resources Foundation, 12.

⁶³ *Ibid*, 12.

⁶⁴ *Ibid*, 12.

⁶⁵ *Morgan Tsvangirai v. Registrar-General and Others* (Judgment HH 29/2002), February 26, 2002.

⁶⁶ *Ibid*.

⁶⁷ *Ibid*.

⁶⁸ G. Friedman, "Tsvangirai v Registrar-General of Elections of Zimbabwe: Report by the Independent Observer to the Forum for Barristers and Advocates of the International Bar Association: notes," *The South African Law Journal* 120, 2 (January 1, 2003): 211.

voting, individuals who were granted orders by magistrate courts to be reinstated on the voters' roll were denied from casting their ballots.⁶⁹

The Registrar General's refusal to renew the passport of an individual with the potential to claim a foreign citizenship was challenged in another 2002 High Court case: *Todd v. Registrar General*. The Registrar General refused to renew the passport of Judith Todd, the daughter of former Rhodesian Prime Minister Sir Garfield Todd, on the grounds that she had lost her Zimbabwean citizenship when she failed to renounce her potential claim to New Zealand citizenship.⁷⁰ The Court found that she was still a Zimbabwean citizen, and ordered her passport to be restored.⁷¹ The government appealed to the Supreme Court, in *Registrar General of Citizenship v. Todd*, and the newly packed Supreme Court sided with the Registrar General.⁷² Todd tried to renounce her potential to claim New Zealand citizenship, but New Zealand said her application could not be processed because she did not have New Zealand citizenship to renounce.⁷³ Despite the Supreme Court's ruling in *Registrar General of Citizenship v. Todd*, the High Court continued to rule against the Registrar General in similar cases.

Job Sibanda, born in Zimbabwe to a Zimbabwean mother and Malawian father, brought a similar case to the High Court in 2002. The Registrar General refused to renew Job Sibanda's passport on the grounds that Sibanda must first renounce his Malawian citizenship by descent, although he never possessed it.⁷⁴ Sibanda was rendered stateless after the Registrar General declared him a non-citizen.⁷⁵ As with the *Todd* decision, in *Job Sibanda v. Registrar-General of Citizenship and Others*, the High Court found that Sibanda was a citizen of Zimbabwe.⁷⁶

Ricarudo Manyere brought a similar case to the High Court in 2002. Manyere was born in Zimbabwe to a Zimbabwean mother and a Mozambican father.⁷⁷ The Registrar General refused to renew Ricarudo Manyere's passport, arguing that he had lost his Zimbabwean citizenship when he failed to renounce his Mozambican citizenship by descent.⁷⁸ In *Ricarudo Manyere v. Registrar General*, the court held that the Registrar General must prove Manyere was a Mozambican citizen by providing a copy of Mozambican citizenship laws that would prove Manyere was a Mozambican citizen.⁷⁹ However, Mozambique did not allow dual citizenship, and citizenship by descent was not automatic. Therefore, Manyere was not a Mozambican citizen and the court ordered the Registrar General to renew Manyere's passport. Despite the ruling, the Registrar General continued to refuse passports to those he considered to have a foreign citizenship or the potential to claim a foreign citizenship.

After protests broke out in southern Africa surrounding the treatment of descendants of migrant workers in Zimbabwe, the government made some concessions.⁸⁰ It amended the Citizenship of Zimbabwe Act in 2003 to allow Zimbabwean-born individuals, whose parents came from Southern

⁶⁹ Manby, "Natives and Settlers," 47.

⁷⁰ *Judith Garfield Todd v. Registrar-General of Citizenship & Minister of Home Affairs* (HC 55/2002), May 7, 2002.

⁷¹ *Ibid.*

⁷² *Registrar General of Citizenship v. Todd* (SC 58/02), February 27, 2003.

⁷³ *Ibid.*

⁷⁴ *Job Sibanda v. Registrar General of Citizenship and Other* (HH 3626/02), February 20, 2005.

⁷⁵ *Ibid.*

⁷⁶ *Ibid.*

⁷⁷ *Ricarudo Manyere v. Registrar General* (HH 87/02), 27 February 2002.

⁷⁸ *Ibid.*

⁷⁹ *Ibid.*

⁸⁰ Manby, "Natives and Settlers," 49.

African Development Community (SADC) states as laborers, to apply for confirmation of their Zimbabwean citizenship and sign a form renouncing their foreign citizenship.⁸¹ In practice, however, Zimbabweans of foreign descent continued to be blocked from accessing their citizenship.⁸²

In 2003, the High Court was faced with yet another case in which an individual with the potential to claim a foreign citizenship lost Zimbabwean citizenship. Lewis Uriri, born in Zimbabwe to Mozambican migrants, tried to obtain a birth certificate for his son.⁸³ The Registrar refused to grant it on the basis that Uriri must first renounce his Mozambican citizenship by descent, despite the fact that he had never claimed it.⁸⁴ In *Lewis Uriri v. Registrar General of Citizenship and Another*, the High Court again ruled that individuals with the potential to claim a foreign citizenship cannot renounce what they do not possess.⁸⁵ Just as the High Court continued to rule against the Registrar General, the Registrar General continued to ignore the High Court and resumed the same practice.⁸⁶

As in the *Todd* and *Sibanda* cases, Trevor Ncube, who was born in Zimbabwe to a Zimbabwean mother and Zambian father, was unable to renew his passport.⁸⁷ The Registrar General refused to renew his passport on the grounds that he must first renounce his Zambian citizenship by descent.⁸⁸ In the 2006 High Court case of *Trevor Ncube v. Registrar General*, the Court ruled that individuals with the potential claim to a foreign citizenship do not need to renounce that claim to access their Zimbabwean citizenship.⁸⁹

In 2009, the Government of National Unity was formed, creating an MDC--ZANU-PF coalition. The coalition government adopted an amendment to the Constitution that did not explicitly ban dual citizenship, but instead allowed parliament to create legislation to ban it.⁹⁰ Despite the change, holders of foreign citizenship were still being blocked from accessing their Zimbabwean citizenship. In 2011, Sebastian Piroro went to the High Court after being denied a passport on the basis of being a dual citizen. Piroro was born in Zimbabwe to a Mozambican father and a Zimbabwean mother. When he tried to renew his passport in 2010, he was denied on the basis that he was a dual citizen of Mozambique and Zimbabwe. The Registrar General argued that he must renounce his Mozambican citizenship, in accordance with Mozambican law, before he can be issued a new Zimbabwean passport. In *Piroro v. Registrar General*, the High Court ruled that the 1984 Citizenship Act's provision requiring a citizen from birth with dual citizenship to renounce the other citizenship to be unconstitutional.⁹¹ Despite the ruling, the Registrar General continued to operate under the pre-2009 Constitutional amendment law that dual citizenship was prohibited for all.⁹²

⁸¹ Manby, "Report on Citizenship Law in Zimbabwe," 6.

⁸² *Ibid.*, 6.

⁸³ *Lewis Uriri v. Registrar General of Citizenship and Another* (HH 7128/03), 2003.

⁸⁴ *Ibid.*

⁸⁵ *Ibid.*

⁸⁶ Manby, "Report on Citizenship Law in Zimbabwe," 17.

⁸⁷ *Trevor Ncube v. Registrar General and Another* (HH 7316/06), 2006.

⁸⁸ *Ibid.*

⁸⁹ *Ibid.*

⁹⁰ Constitution of Zimbabwe Amendment (No.19) Act, 2009.

⁹¹ Manby, "Report on Citizenship Law in Zimbabwe," 7.

⁹² *Ibid.*, 7.

2013 CONSTITUTION AND THE CONSTITUTIONAL COURT

In 2013, the coalition government adopted a new constitution that provided dual citizenship for Zimbabwean citizens by birth, but maintained that parliament retains the power to prohibit dual citizenship from registered citizens and citizens by descent.⁹³ However, legal questions surrounding dual citizenship still persist. Because it took until 2019 for the 1984 Citizenship Act to be amended in accordance with the new constitution, dual citizenship was prohibited in practice.⁹⁴ The Registrar General continued to deny citizenship to those with the potential claim to a foreign citizenship. Further, the allowance of dual citizenship is unpopular among Zimbabweans. In 2012, immediately before the Constitution was adopted, AfroBarometer found that 71 percent of Zimbabweans believed that an individual who wished to hold dual citizenship should not have the right to be a citizen of Zimbabwe.⁹⁵

The 2013 Constitution also created a constitutional court, which became the final court of appeal for questions of "constitutional matters."⁹⁶ The new Constitution specified that the Constitutional Court bench would seat a chief justice, a deputy chief justice, and five other justices, while maintaining the 1980 Constitution's minimal requirement of "no fewer than two" justices on the Supreme Court bench.⁹⁷ The 2013 Constitution included a provision that reduced the president's power in judicial appointments. The Judicial Service Commission (JSC) is an agency that acts as a "watchdog to conduct checks and balances over the president and ensures that judicial appointments are made without any undue political influence."⁹⁸ While the commission was provided for in the 1980 Constitution, the 2013 Constitution granted it enhanced powers. When a judge position opens up on the High Court, Supreme Court, or Constitutional Court, the JSC must advertise the vacancies and hold public interviews with the candidates.⁹⁹ Then, the JSC prepares a list of three qualified candidates to submit to the president, from which the president must select.¹⁰⁰ This provision weakens the president's capacity to appoint loyalists to the judiciary because he or she can only select appointees that have been vetted by the JSC.

However, the JSC is not foolproof. Because the Commission is partly composed of members appointed by the president, it runs the risk of being filled with presidential loyalists who could nominate other loyalists to judicial positions. When the 2013 Constitution was adopted, there was a seven-year transition period before the JSC could start working to fill the Constitutional Court.¹⁰¹ During the transitional phase, during which the following cases were decided, the Constitutional Court consisted of the Chief Justice, the Deputy Chief Justice, and seven judges of the Supreme Court, many of whom were Mugabe appointments.¹⁰² However, the Constitutional Court followed the trend set by the High Court of upholding citizenship rights, rather than the Supreme Court's

⁹³ Constitution of Zimbabwe, 2013, Section 42(e).

⁹⁴ Chipenda, 8.

⁹⁵ Eldred V. Masunungure; Heather Koga, "Zimbabweans' (Mostly) Tolerant Views on Citizenship," AfroBarometer,

Briefing Paper No. 16 (March 2013): 3.

⁹⁶ Constitution of Zimbabwe, 2013, 167(1)(a).

⁹⁷ *Ibid*, 168(1)(b).

⁹⁸ Amanda Shivamba, "An Analysis of Zimbabwe's Proposed Constitutional Amendment Related to the Judiciary," *Southern African Litigation Centre*, No. 3 (2020): 1-6.

⁹⁹ Constitution of Zimbabwe, 2013, 180(4).

¹⁰⁰ *Ibid*, 180(4).

¹⁰¹ "Court Watch 11-2021 - Appointment of Constitutional and Supreme Court Judges," *VertiasZim* (2021).

¹⁰² *Ibid*.

precedent of denying citizenship rights. This can be explained by a decrease in the political saliency of questions of dual citizenship, not by the enhanced powers of the JSC. Because of the new unity government, the judiciary felt less pressure to rule in accordance with President Mugabe's former attempts to consolidate power by means of stripping citizenship from those with ties to foreign countries. Further, with the land reform program already implemented, there was less pressure to rule on behalf of the government from a policy standpoint.

Since the promulgation of the 2013 Constitution, the new Constitutional Court has heard several cases related to dual citizenship laws. In 2013, the court heard *Mawere v. Registrar General & Others*. Zimbabwean businessman Mutumwa Mawere was born in the country to parents who were also born in Zimbabwe, but he eventually acquired South African citizenship.¹⁰³ After losing his Zimbabwean national identity document, Mawere went to the Registrar General's office to get a duplicate.¹⁰⁴ Without the national identity document, he would be unable to register as a voter before the 2013 election.¹⁰⁵ However, he was unable to get his Zimbabwean national identity document because he remained a South African citizen.¹⁰⁶ The Constitutional Court upheld Mawere's right to Zimbabwean citizenship without having to renounce his acquired South African citizenship.¹⁰⁷

In 2014, the Constitutional Court heard the case of *Madzimbamuto v. Registrar General & Others*. Madzimbamuto was born in Zimbabwe to one Zimbabwean parent and one South African.¹⁰⁸ He was unable to submit an application to renew his Zimbabwean passport after enduring long lines and bureaucratic obstacles at the Registrar General's office. So, he obtained South African citizenship through his mother.¹⁰⁹ In 2012, Madzimbamuto returned to Zimbabwe permanently and applied for citizenship when the 2013 Constitution was promulgated, but was denied.¹¹⁰ The Constitutional Court confirmed Madzimbamuto's right to dual Zimbabwean and South African nationality.¹¹¹

In 2017, the High Court heard the case of *MDC-T, MDC-N, and Kachingwe v. ZEC, Registrar-General, Minister of Home Affairs, & ZANU-PF*. The MDC argued that its members were at risk of being disenfranchised because those possessing identity documents demarcated 'alien' were denied the right to register to vote; the Registrar General refused to give them citizen ID cards.¹¹² The High Court issued an order that those with an 'alien' identity card who had connections to another southern African country should be able to register to vote without further confirmation of citizenship.¹¹³ However, the Zimbabwe Election Support Network, a union of civil society organizations, found that individuals holding alien ID cards faced challenges registering to vote in the 2018 election.¹¹⁴

¹⁰³ *Mutumwa Dziva Mawere v. Registrar General & Ors* (CC 27/13), June 25, 2013.

¹⁰⁴ *Ibid.*

¹⁰⁵ *Ibid.*

¹⁰⁶ *Ibid.*

¹⁰⁷ *Ibid.*

¹⁰⁸ *Ibid.*

¹⁰⁹ *Farai Daniel Madzimbamuto v. Registrar General & Ors* (CC 114/13), February 12 & June 25, 2014.

¹¹⁰ *Ibid.*

¹¹¹ *Ibid.*

¹¹² *Movement for Democratic Change (T) and Movement for Democratic Change (N) and Sarah Kachingwe v. Zimbabwe Electoral Commission and Registrar General N.O and Minister of Home Affairs and Zimbabwe African National Union Patriotic Front (ZANU-PF)* (HC 10623/17), November 29, 2017.

¹¹³ Manby, "Report on Citizenship Law in Zimbabwe," 16.

¹¹⁴ *Ibid.*, 16.

CONCLUSION

Although the 2013 Constitution provides for dual citizenship, those with connections to other southern African countries still struggle to access their citizenship rights. During the Mugabe-era, the High Court upheld the rights of the descendants of migrant workers to citizenship, but the Registrar General refused to comply with its rulings. Further, the Supreme Court overturned the High Court's decision in *Registrar General of Citizenship v. Todd*, thereby giving legitimacy to the Registrar General's refusal to comply with High Court rulings. It took until 2019 for the Citizenship Act to be brought in line with the Constitution.¹¹⁵ This delay made it possible for the Registrar General to continue denying citizenship rights to those with dual citizenship and those with the potential claim to dual citizenship after the 2013 Constitution was adopted.

The difference between the High Court's and Supreme Court's rulings on questions of dual citizenship reflect upon the hierarchical structure of the judicial system. The Supreme Court, being the final court of appeal until 2013, was under increased pressure to rule on the side of the Mugabe government when a dual citizenship case went to the court. The High Court, whose decisions could be appealed, felt less political pressure to side with the regime, knowing that the Registrar General would appeal to a packed Supreme Court that would overturn the ruling. The Constitutional Court was operating in an environment in which questions of dual citizenship became less politically salient. With a unity government and the land reform program already implemented, the court upheld individuals' citizenship rights.

Today, the judiciary and the 2013 Constitution are under assault, opening up the possibility that questions of dual citizenship could return to the courts. Because the seven-year transition phase that provided for the temporary appointment of high-ranking judges to the Constitutional Court ended in 2020, President Emmerson Mnangagwa has sought to manipulate the judiciary. In 2021, the Constitution was amended to increase the mandatory retirement age for judges from seventy to seventy-five.¹¹⁶ Further, High Court, Supreme Court, and Constitutional appointments can now be made by the President, without conducting public nominations and interviews, which were originally provided for in the 2013 Constitution.¹¹⁷ However, these amendments are beginning to be challenged in the courts. The High Court has already ruled that extending the mandatory retirement age is unconstitutional.¹¹⁸ While the cases are still unfolding, it is promising that the High Court has already declared Mnangagwa's manipulation of the retirement age unconstitutional. As Zimbabwe continues to struggle with democratization, and the courts are left increasingly judicialized, the possibility that questions surrounding citizenship will return to the courts remains.

¹¹⁵ "Govt To Amend Dual Citizenship Provisions To Align With The Constitution," *ZimEye: The Truth & The Future*, (February 27, 2019).

¹¹⁶ Arthur G. O. Mutumbara, "Constitutional Amendment: Implications for Democracy and Constitutionalism," *ZimLive* (May 7, 2021).

¹¹⁷ *Ibid.*

¹¹⁸ Macdonald Dzirutwe, "Zimbabwe Court Rules Chief Justice's Tenure Extension is Invalid," *Reuters* (May 15, 2021).

Bibliography

- "A Right or a Privilege: Access to Identity and Citizenship in Zimbabwe." *Research & Advocacy Unit* (December 2008): 1-29.
- Alexander, Peter. "Zimbabwean Workers, the MDC & the 2000 Election." *Review of African Political Economy* 85 (February 2007): 385.
- Amnesty International. "We are like Stray Animals: Thousands Living on the Margins due to Statelessness in Zimbabwe," 2021.
- Bureau of African Affairs. "Loss of Two Zimbabwe Supreme Court Justices Strengthens ZANU-PF's Influence Over Bench." Wikileaks Cable: 02HARARE38_a, dated January 4, 2002. https://wikileaks.org/plusd/cables/02HARARE38_a.html.
- Carr v. Registrar-General*, 2000 (2) ZLR 433 (S).
- Chipenda, Clement. "Land Reform, Citizenship, and Aliens in Zimbabwe." *Africa Review* 13, 1 (2020): 12-39.
- Constitution of Zimbabwe Amendment (No.19) Act, 2009.
- Citizenship of Zimbabwe Act, section 9, as amended Act No. 12 of 2001.
- Constitution of Zimbabwe, 1980.
- Constitution of Zimbabwe, 2013.
- "Court Watch 11-2021 - Appointment of Constitutional and Supreme Court Judges," *VeritasZim* (2021). <http://www.veritaszim.net/node/5071>.
- Daimon, Anusa. "Politics of 'Othering' and the Struggle for Citizenship in Independent Zimbabwe." *Africa Insight* 44, 1 (2014), 137-150.
- Daimon, Anusa. "ZANU (PF) 's Manipulation of the 'Alien' Vote in Zimbabwean Elections: 1980-2013." *South African Historical Journal* 68, 1 (2016): 112-132.
- Dzirutwe, Macdonald. "Zimbabwe Court Rules Chief Justice's Tenure Extension is Invalid," *Reuters* (May 15, 2021).
- Farai Daniel Madzimbamuto v. Registrar General & Ors* (CC 114/13), February 12 & June 25, 2014.
- Fisher, J. L. "Decolonising Settler Citizenship: The Decolonisation of White Identity in Zimbabwe," in *Pioneers, Settlers, Aliens, Exiles* (Canberra, Australia: The Australian National University, 2010), 103-130.
- Friedman, G. "Tsvangirai v Registrar-General of Elections of Zimbabwe: Report by the Independent Observer to the Forum for Barristers and Advocates of the International Bar Association: notes." *The South African Law Journal* 120, 2 (January 1, 2003).
- George, Jessica P.; Elphick, Rosalind. "Statelessness and Nationality in South Africa." *Lawyers for Human Rights and the UNHCR*, (March 2013): 1-86.
- "Govt To Amend Dual Citizenship Provisions To Align With The Constitution." *ZimEye: The Truth & The Future*, (February 27, 2019).
- Hatchard, John. "The Constitution of Zimbabwe: Towards a Model for Africa?" *Journal of African Law* 35, 1/2 (1991): 79-101.
- Hirschl, Ran. "The Judicialization of Mega-Politics." *The Political Science Review*, (2008): 93-118.
- Hirschl, Ran. "The Judicialization of Politics." *The Oxford Handbook of Political Science*, (2011): 1-24.

- Job Sibanda v. Registrar General of Citizenship and Other* (HH 3626/02), February 20, 2005.
- Judith Garfield Todd v. Registrar-General of Citizenship & Minister of Home Affairs* (HC 55/2002), May 7, 2002.
- Justice Gubbay, Anthony R. "The progressive Erosion of the Rule in Zimbabwe." From the *Third International Rule of Law Lecture: Bar of England and Wales* (December 9, 2009): 1-26.
- "Justice in Zimbabwe." *Legal Resources Foundation, Zimbabwe* (September 30, 2002): 1-140.
- Kruger, Norma J. "Robert Mugabe, Another Long Too-Serving African Ruler: A Review Essay." *Political Science Quarterly* 118, 2 (2003): 307-313.
- Lawyers for Human Rights, *Statelessness and Nationality in South Africa*, 2011, 19.
- Lewis Uriri v. Registrar General of Citizenship and Another* (HH 7128/03), 2003.
- Magaramombe, Godfrey. "Rural poverty: Commercial farm workers and Land Reform in Zimbabwe." *SARPN Conference on Land Reform and Poverty Alleviation in Southern Africa Pretoria* (June 4-5, 2001): 1-9.
- Mahove, Christopher. "Mugabe's Demise Brings Hope to Zimbabwe's Ousted White Farmers." *Reuters* (January 30, 2018).
- Manby, Bronwen. "Natives and Settlers." In *Struggles for Citizenship in Africa* (London, United Kingdom: Zed Books, 2011), 37-93.
- Manby, Bronwen. "Report on Citizenship Law in Zimbabwe." *European University Institute: Robert Schuman Centre for Advanced Studies* (January 2019): 1-17.
- Masengu, Tabath. "The Vulnerability of Judges in Southern Africa: Alarming Trends." *Africa Today* 63, 4 (Summer 2017): 3-19.
- Masunungure, Eldred V.; Koga, Heather. "Zimbabweans' (Mostly) Tolerant Views on Citizenship." *AfroBarometer*, Briefing Paper No. 16 (March 2013): 1-8.
- Mlambo, Alois S. "Becoming Zimbabwe or Becoming Zimbabwean: Identity, Nationalism, and State-Building." *Africa Spectrum* 48, 1 (2013): 49-70.
- Morgan Tsvangirai v. Registrar-General and Others* (Judgment HH 29/2002), February 26, 2002.
- Movement for Democratic Change (T) and Movement for Democratic Change (N) and Sarah Kachingwe v. Zimbabwe Electoral Commission and Registrar General N.O and Minister of Home Affairs and Zimbabwe African National Union Patriotic Front (ZANU-PF)* (HC 10623/17), November 29, 2017.
- "Mugabe Accused of Nominating Sympathetic Judges." *Breaking News, Cork* (July 27, 2001).
- "Mugabe Appoints his Judges." *News24*, (July 27, 2001).
- "Mugabe Appoints Three New Judges." *The New Humanitarian* (July 27, 2001).
- "Mugabe Demands Zimbabwean Judges Quit President Bristles at Criticism of Human-Rights Record after Journalists Say they were Tortured." *The Globe and Mail, Toronto*, (February 8, 1999).
- "Mugabe Regime Prepares to Axe White Judges." *The Guardian* (June 4, 2000).
- Mutumbara, Arthur G. O. "Constitutional Amendment: Implications for Democracy and Constitutionalism," *ZimLive* (May 7, 2021).
- Mutumwa Dziva Mawere v. Registrar General & Ors (CC 27/13), June 25, 2013.
- Ndakaripa, Musiwaro. "The State and Contested Citizenship in Zimbabwe, 1980-2011" in *Nationalism and National Projects on Southern Africa* (Pretoria, South Africa: Africa Institute of South Africa, 2013), 294-320.
- Registrar General of Citizenship v. Todd* (SC 58/02), February 27, 2003.

- “Retired Supreme Court Justice Nicholas McNally Dies.” *Zimbabwe Situation* (January 25, 2021).
- Ricarudo Manyere v. Registrar General* (HH 87/02), February 27, 2002.
- Shivamba, Amanda. “An Analysis of Zimbabwe’s Proposed Constitutional Amendments Related to the Judiciary.” *Southern African Litigation Centre*, No. 3 (2020): 1-6.
- Trevor Ncube v. Registrar General and Another* (HH 73\16/06), 2006.
- “Zimbabwe Leader Swears in Three Supreme Court Judges.” *BBC Monitoring Newsfile, London*, (August 2, 2001).
- “Zimbabwe Premier’s Office Working on Proposal to Change Citizenship Laws.” *BBC Monitoring Africa* (London, United Kingdom: SW Radio Africa, August 20, 2009),
- “Zimbabwe's Opposition Party Files Petitions Against Poll Results.” *Xinhua* (April 20, 2005).

Analysis of the Mechanism of the Chinese Anti-Unfair Competition Law Protecting Unregistered Trademarks from a Comparative Perspective: The United States and China

Zheng Qin

Keywords— unregistered trademark, unfair competition, secondary meaning, trade dress.

Abstract— In China, the protection of unregistered trademarks under the Anti-Unfair Competition Law is carried out from the perspective of preventing counterfeiting and preventing consumer confusion. This article argues that the commodity name, packaging, and decoration having a certain influence stipulated in Article 6 of the 2019 Chinese Anti-Unfair Competition Law in force are actually the protection of unregistered trademarks. For intellectual property, all acts (e.g., counterfeiting) that infringe on others' intellectual property interests to gain competitive market advantage, harm the interests of operators and consumers and disrupt market order are within the scope of the Anti-Unfair Competition Law. Counterfeit use of others' unregistered trademarks and illegal use of others' goodwill are undoubtedly acts of unfair competition. Based on the existence of a large number of unregistered trademarks in the market, their interests belong to the scope of protection of the Anti-Unfair Competition Law. In a market economy, unregistered trademarks accumulate honest business operators' efforts through use, and their business achievements, such as goodwill, belong to the labor achievements of right holders. The legislative design of the Anti-Unfair Competition Law protecting commercial signs having a certain influence aims to ensure market competition to enjoy and use business achievements safely in economic transactions. When some dishonest business operators violate laws and use others' commodity names, packaging, and decorations having a certain influence in order to gain market shares, causing confusion with other people's commodities, the Anti-Unfair Competition Law is needed to stop such acts. In addition, based on the analysis and comparison with "secondary meaning" in US trademark law, the author concluded that this theory has some similarities with the protection of commercial signs in the Chinese legal system. Both systems protect commercial signs that "acquire distinctiveness through use" and have goodwill. Also, the author compares the concept of "trade dress" in the American law with the concept and principle of "packaging and decoration" in the Chinese Anti-Unfair Competition Law to find that the object scope covered by trade dress is broader than packaging and decoration in Chinese law while the legal principles behind them are the same. In accordance with the Lanham Act, as long as the trade dress is non-functional and distinctive, it can be protected. China was experiencing a large number of counterfeiting and free-riding with regard to well-known goods within the market. In order to combat this and seek remedies, the owners of the well-known unregistered commercial signs would cite the 1993 law. This law applied to "specific names, packaging, and decoration of well-known commodities. However, the current 2019 Anti-Unfair Competition Law no longer restricts the condition of "well-known" but focuses on "making others mistakenly believe the specific connection." US trade dress law has similar principles, namely, protecting commercial signs that are recognizable in the eyes of the public to prevent counterfeiting and free-riding.

A Constitutional Theory of the American Presidency

Elvin Lim

Abstract— This article integrates the debate about presidential powers with the debate about federalism, arguing that there are two ways of exercising presidential powers, one working in tandem with expanding federal powers, and the other working against it. Alexander Hamilton and Thomas Jefferson—the former a Federalist and the latter echoing the views of many Anti-Federalists—disagreed not only on the constitutional basis of prerogative, but also on the ends for which it should be deployed. This tension has always existed in American politics, and is reproduced today. Modern Democrats and Republicans both want a strong executive, but the Democrats who want a strong executive to pass legislation to expand the reach of the federal government; naturally, they must rely on an equally empowered Congress to do so. Republicans generally do not want an intrusive federal government, which is why their defense of a strong presidency does not come alongside a call for a strong Congress. This distinction cannot be explained without recourse to foundational yet opposing views about the appropriate role of federal power. When we bring federalism back in, we see that there are indeed two presidencies; one neo-Federalist, in favor of moderate presidential prerogative alongside a robust Congress directed collectively to a national state-building agenda and expanding the federal prerogative; another, neo-Anti-Federalist, in favor of expansive presidential prerogative and an ideologically sympathetic Congress equally suspicious of federal power to retard or roll back national state-building in favour of states rights.

Keywords— US presidency, federalism, prerogative, anti-federalism.

A Matter of Trust – The Role of Competitive Markets and its Impact on the Data Privacy Rights of Online Consumers in India: An Analytical Study

Vinay Sharma

Abstract— Advancement in technology and the aftermaths of pandemic business enterprises, Governments and the organizations, have been looking at new business models, in the domain of online business transactions, to facilitate the growth of their business; nevertheless, they face the governance and legal challenges in online business, under data protection, violation of privacy regulations, consumer protection, money laundering violations. Information and technology communication have changed the way that business transactions are done across the spectrum, by business houses and consumers in the modern-day global markets. The advent of the pandemic has also hastened the way that business houses have to adapt their business models, to the deliverance of the products and services, through the use of e-commerce platforms.

The said issues and concerns have been studied through empirical, descriptive and analytical research methodologies. A sample of around 500+ customers have been collected for understanding and evaluating the implications of various infringements and violations of digital transactions norms.

Over the last five years, the development of the e-commerce industry in India has mushroomed heavily, and it is estimated that the business may touch about 350 million buyers by 2025. As more and more consumers use e-commerce seamlessly, there are worries, on the issues of personal data protection and data privacy, along with the cyber-crime. As e-commerce companies process a huge amount of data from user clicks, to personal information of credit/debit cards for an elevated shopping experience; there have been rising instances of data breaches and personal sensitive information, that has reached to third parties, who have accessed the same for their personal gains.

The Government of India in this regard, has sought to protect the data of its citizens, by enacting a law for the same through “*The Personal Data Protection Bill, 2019*”, which was given assent by the Union Cabinet in India, however it is still to be ratified into an Act, as it goes through the grind of legal intricacies, and the executives having its own views on the issue of data protection and privacy. As the Personal Data Protection Bill, 2019 has not yet seen the light of the day, complaints against e-commerce companies, along with consumers upping the ante, on the protection of consumer rights. As a result, the Government of India has introduced the Consumer Protection (E-Commerce) Rules, 2020, which has been further amended in 2021.

This paper objectively aims to analyse, the legal perspectives of e-commerce transactions, and its interplay with consumer protection, in view of the breach of data privacy, data protection and use of sensitive data for cyber frauds. The paper also seeks to examine, the role of competition laws in India, in view of the creation of a Parliamentary panel for anti-competitive practices, through setting up

of a Digital Markets and Data Unit against Google, Amazon, Meta (Facebook) and Twitter to examine their competitive behaviour in online transactions.

Keywords— Data Privacy, Digital Transactions, Consumer Protection, Personal Data Protection Bill

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The International Criminal Court's Intimate Immensity

Ruby Lindiwe Turok-Squire

Abstract— This paper argues that intimate immensity underpins International Criminal Law and the International Criminal Court, such that the ICC reflects and supports a dynamic central to ICL's practice. This co-operation of written and spatial elements of the law reinforces the law's legitimacy and helps to make it 'real in people's minds', to quote Vos and Stolk. It may even enable a branding of ICL, by endorsing ICL's principle of intimate immensity and thereby assisting ICL in gaining legitimacy and achieving the immense stature and universal applicability to which it aspires.

Keywords— ICC, ICL, intimate immensity, Bachelard, Legitimacy, Architecture.

Exposure to Nature: An Underutilized Component of Student Mental Health

Jeremy Bekker, Guy Salazar

Abstract— Introduction: Nature-exposure interventions on university campuses may serve as an effective addition to overburdened counseling and student support centers. Nature-exposure interventions can work as a preventative well-being enhancement measure on campuses, which can be used adjacently with existing health resources. Specifically, this paper analyzes how spending time in nature impacts psychological well-being, cognitive functioning, and physical health. The poster covers the core findings and recommendations of this paper, which has been previously published in the BYU undergraduate psychology journal *Intuition*. Research Goals and Method: The goal of this paper was to outline the potential benefits of nature exposure for students' physical health, mental well-being, and academic success. Another objective of this paper was to outline potential research-based interventions that use campus green spaces to improve student outcomes. Given that the core objective of this paper was to identify and establish research-based nature exposure interventions that could be used on college campuses, a broad literature review focused on these areas. Specifically, the databases Scopus and PsycINFO were used to screen for research focused on psychological well-being, physical health, cognitive functioning, and nature exposure interventions. Outcomes: Nature exposure has been shown to help increase positive affect, life satisfaction, happiness, coping ability and subjective well-being. Further, nature exposure has been shown to decrease negative affect, lower mental distress, reduce cognitive load, and decrease negative psychological symptoms. Finally, nature exposure has been shown to lead to better physical health. Findings and Recommendations: Potential interventions include adding green space to university buildings and grounds, dedicating already natural environments as nature restoration areas, and providing means for outdoor excursions. Potential limitations and suggested areas for future research are also addressed. Many campuses already contain green spaces, defined as any part of an environment that is predominately made of natural elements, and these green spaces comprise an untapped resource that is relatively cheap and simple.

Keywords— nature exposure, preventative care, undergraduate mental health, well-being intervention.

Disseminating Positive Psychology Resources Online: Current Research and Future Directions

Warren Jared, Bekker Jeremy, Salazar Guy, Jackman Katelyn, Linford Lauren

Abstract— Introduction: Positive Psychology research has burgeoned in the past 20 years; however, relatively few evidence-based resources to cultivate positive psychology skills are widely available to the general public. The positive psychology resources at www.mybestself101.org were developed to assist individuals in cultivating well-being using a variety of techniques, including gratitude, purpose, mindfulness, self-compassion, savoring, personal growth, and supportive relationships. These resources are empirically based and are built to be accessible to a broad audience. Key Objectives: This presentation highlights results from two recent randomized intervention studies of specific MBS101 learning modules. A key objective of this research is to empirically assess the efficacy and usability of these online resources. Another objective of this research is to encourage the broad dissemination of online positive psychology resources; thus, recommendations for further research and dissemination will be discussed.

Methods: In both interventions, we recruited adult participants using social media advertisements. The participants completed several well-being and positive psychology construct-specific measures (savoring and self-compassion measures) at baseline and post-intervention. Participants in the experimental condition were also given a feedback questionnaire to gather qualitative data on how participants viewed the modules. Participants in the self-compassion study were randomly split between an experimental group, who received the treatment, and a control group, who were placed on a waitlist. There was no control group for the savoring study. Participants were instructed to read content on the module and practice savoring or self-compassion strategies listed in the module for a minimum of twenty minutes a day for 21 days. The intervention was semi-structured, as participants were free to choose which module activities they would complete from a menu of research-based strategies. Participants tracked which activities they completed and how long they spent on the modules each day. Results: In the savoring study, participants increased in savoring ability as indicated by multiple measures. In addition, participants increased in well-being from pre- to post-treatment. In the self-compassion study, repeated measures mixed model analyses revealed that compared to waitlist controls, participants who used the MBS101 self-compassion module experienced significant improvements in self-compassion, well-being, and body image with effect sizes ranging from medium to large. Attrition was 10.5% for the self-compassion study and 71% for the savoring study. Overall, participants indicated that the modules were generally helpful, and they particularly appreciated the specific strategy menus. Participants requested more structured course activities, more interactive content, and more practice activities overall. Recommendations: Mybestself101.org is an applied positive psychology research program that shows promise as a model for effectively disseminating evidence-based positive psychology resources that are both engaging and easily accessible. Considerable research is still needed, both to test the efficacy and usability of the modules currently available and to improve them based on participant feedback. Feedback received from participants in the randomized controlled trial led to the development of an expanded, 30-day online course called The Gift of Self-Compassion and an online mindfulness course currently in development called Mindfulness For Humans.

Keywords— positive psychology, intervention, online resources, self-compassion, dissemination, online curriculum.

Mobile Application Interventions in Positive Psychology: Current Status and Recommendations for Effective App Design

Gus Salazar, Jeremy Bekker, Lauren Linford, Jared Warren

Abstract— Positive psychology practices allow for its principles to be applied to all people, regardless of their current level of functioning. To increase the dissemination of these practices, interventions are being adapted for use with digital technology, such as mobile apps. However, the research regarding positive psychology mobile app interventions is still in its infancy. In an effort to facilitate progress in this important area, we 1) conducted a qualitative review to summarize the current state of the positive psychology mobile app literature and 2) developed research-supported recommendations for positive psychology app development to maximize behavior change. In our literature review, we found that while positive psychology apps varied widely in content and purpose, there was a near-complete lack of research supporting their effectiveness. Most apps provided no rationale for the behavioral change techniques (BCTs) they employed in their app, and most did not develop their app with specific theoretical frameworks or design models in mind. Given this problem, we recommended four steps for effective positive psychology app design. First, developers must establish their app in a research-supported theory of change. Second, researchers must select appropriate behavioral change techniques which are consistent with their app's goals. Third, researchers must leverage effective design principles. These steps will help mobile applications use data-driven methods for encouraging behavior change in their users. Lastly, we discuss directions for future research. In particular, researchers must investigate the effectiveness of various BCTs in positive psychology interventions. Although there is some research on this point, we do not yet clearly understand the mechanisms within the apps that lead to behavior change. Additionally, app developers must also provide data on the effectiveness of their mobile apps. As developers follow these steps for effective app development and as researchers continue to investigate what makes these apps most effective, we will provide millions of people in need with access to research-based mental health resources.

Keywords— behavioral change techniques, mobile app, mobile intervention, positive psychology.

Psychometric Properties of Several New Positive Psychology Measures

Lauren Benyo Linford, Jared Warren, Jeremy Bekker, Gus Salazar

Abstract— In order to accurately identify areas needing improvement and track growth, the availability of valid and reliable measures of different facets of well-being is vital. Because no specific measures currently exist for many facets of well-being, the purpose of this study was to construct and validate measures of the following constructs: Purpose, Values, Mindfulness, Savoring, Gratitude, Optimism, Supportive Relationships, Interconnectedness, Compassion, Community, Contribution, Engaged Living, Personal Growth, Flow Experiences, Self-Compassion, Exercise, Meditation, and an overall measure of subjective well-being—the Survey on Flourishing. In order to assess their psychometric properties, each measure was examined for internal consistency estimates, and items with poor item-test correlations were dropped. Additionally, the convergent validity of the Survey on Flourishing (SURF) was assessed. Total score correlations of SURF and other commonly used measures of well-being such as the Positive and Negative Affect Schedule (PANAS), The Satisfaction with Life Scale (SWLS), the PERMA Profiler (measure of Positive Emotion, Engagement, Relationships, Meaning, and Achievement) were examined to establish convergent validity. The Kessler Psychological distress scale (K6) was also included to determine the divergent validity of the SURF measure. Three week test-retest reliability was also assessed for the SURF measure. Additionally, normative data from general population samples was collected for both the Self-Compassion and Survey on Flourishing (SURF) measures. The purpose of this study is to introduce each of these measures, divulge the psychometric findings of this study, as well as explore additional psychometric properties of the SURF measure in particular. This study will highlight how these measures can be used in future research exploring these positive psychology constructs. Additionally, this study will discuss the utility of these measures to guide individuals in their use of the online self-directed, self-administered My Best Self 101 positive psychology resources developed by the researchers. The goal of My Best Self 101 is to disseminate real, research-based measures and tools to individuals who are seeking to increase their well-being.

Keywords— measurement, psychometrics, test validation, well-being.

Emotion Motives Predict the Mood States of Depression and Happiness

Paul E. Jose

Keywords—emotion motives, depression, subjective happiness, path model

Abstract—A new self-report measure named the General Emotion Regulation Measure (GERM) assesses four key goals for experiencing broad valenced groups of emotions: 1) trying to experience positive emotions (e.g., joy, pride, liking a person); 2) trying to avoid experiencing positive emotions; 3) trying to experience negative emotions (e.g., anger, anxiety, contempt); and 4) trying to avoid experiencing negative emotions. Although individual differences in GERM motives have been identified, evidence of validity with common mood outcomes is lacking. In the present study, whether GERM motives predict self-reported subjective happiness and depressive symptoms (CES-D) was tested with a community sample of 833 young adults. It was predicted that the GERM motive of trying to experience positive emotions would positively predict subjective happiness, and analogously trying to experience negative emotions would predict depressive symptoms.

An initial path model was constructed in which the four GERM motives predicted both subjective happiness and depressive symptoms. The fully saturated model included three non-significant paths, which were subsequently pruned, and a good fitting model was obtained (CFI = 1.00; RMR = .007). Two GERM motives significantly predicted subjective happiness: 1) trying to experience positive emotions ($\beta = .38, p < .001$) and 2) trying to avoid experiencing positive emotions ($\beta = -.48, p < .001$). Thus, individuals who reported high levels of trying to experience positive emotions reported high levels of happiness, and individuals who reported low levels of trying to avoid experiencing positive emotions also reported high levels of happiness. Three GERM motives significantly predicted depressive symptoms: 1) trying to avoid experiencing positive emotions ($\beta = .20, p < .001$); 2) trying to experience negative emotions ($\beta = .15, p < .001$); and 3) trying to experience positive emotions ($\beta = -.07, p < .001$).

In agreement with predictions, trying to experience positive emotions was positively associated with subjective happiness and trying to experience negative emotions was positively associated with depressive symptoms. In essence, these two valenced mood states seem to be sustained by trying to experience similarly-valenced emotions. However, the three other significant paths in the model indicated that emotion motives play a complicated role in supporting both positive and negative mood states. For subjective happiness, the GERM motive of not trying to avoid positive emotions, i.e., not avoiding happiness, was also a strong predictor of happiness. Thus, people who report being the happiest are those individuals who not only strive to be experience positive emotions but also are not ambivalent about them. The pattern for depressive symptoms was more nuanced. Individuals who reported higher depressive symptoms also reported higher levels of avoiding positive emotions and trying to experience negative emotions. The strongest predictor for depressed mood was avoiding positive emotions, which would suggest that happiness aversion or fear of happiness is an important motive for dysphoric people. Future work should determine whether these patterns of association are similar among clinically depressed people, and longitudinal data are needed to determine temporal relationships between motives and mood states.

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Subjective Well-being, Beliefs, and Lifestyles of First Year University Students in the UK

Kaili C. Zhang

Abstract— Mental well-being is an integral part of university students' overall well-being and has been a matter of increasing concern in the UK. This study addressed the impact of university experience on students by investigating the changes students experience in their beliefs, lifestyles, and well-being during their first year of study, as well as the factors contributing to such changes. Using a longitudinal two-wave mixed method design, this project identified important factors that contribute to or inhibit these changes. Implications for universities across the UK are discussed.

Keywords— subjective well-being, beliefs, lifestyles, university students.

Gender Differences in the Impact and Subjective Interpretation of Childhood Sexual Abuse Survivors

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Abstract—Research on child sexual abuse have predominantly focused on female survivors. This has resulted in less research looking at the particular context in which this abuse takes place for boys and the impact this abuse may have on male survivors. The aim of this study is to examine the sex and age of the perpetrators of child sexual abuse and explore gender differences in the impact along with the subjective interpretation that survivors attribute to these experiences. The data for this study was obtained from Ecuadorian university students (M = 230, F = 293) who reported sexual abuse using the ISPCAN Child Abuse Screening Tool Retrospective version (ICAST-R). Participants completed Horowitz's Impact of Event Scale (IES) and were also requested to choose among neutral, positive, and negative adjectives to describe these experiences. The results indicate that in the case of males, perpetrators were both males (adults =27%, peers =20%, relatives =10.3%, cousins =7.4%) and young females (girlfriends or ex-girlfriends =25.6%, neighborhood =20.7%, school =16.7%, cousins =15.3%, strangers =12.8%). In contrast, almost all females reported that adult males were the perpetrators (relatives =29.6%, neighborhood =11.9%, strangers =19.9%, family friends =9.7%). Regarding the impact of these events, significant gender differences emerged. More females (50%) than males (20%) presented symptoms of Post-Traumatic Stress Disorder (PTSD). Gender differences also surfaced in the way survivors interpret their experiences. Almost half of the male participants selected the word "consensual" followed by the words "normal", "helped me to mature", "shameful", "confusing", and "traumatic". In contrast, almost all females chose the word "non-consensual" followed by the words "shameful", "traumatic", "scary", and "confusing". In conclusion, the findings of this study suggest that young females and adult males were the most common perpetrators of sexually abused boys whereas adult males were the most common perpetrators of sexually abused girls. The impact and the subjective interpretation of these experiences were more negative for girls than for boys. The factors that account for the gender differences in the impact and the interpretation of these experiences need further exploration. It is likely that the cultural expectations of sexual behaviors for boys and girls in Latin American societies may partially explain the differential impact in the way these childhood sexual abuse experiences are interpret in adulthood. In Ecuador, as is the case of other Latin American countries, the machismo culture not only accepts but encourages early sexual behaviors in boys and negatively judges premature sexual behavior in females. The result of these different sexual expectations may be that sexually abused boys may re-define these experiences as "consensual" and "normal" in adulthood, even though these were not consensual at the time of occurrence. Future studies are needed to more deeply understand the different contexts of sexual abuse for boys and girls in order to analyze the long-term impact of these experiences.

Keywords—Abuse, Child, Gender differences, Sexual.

Investigating the Effect of Executive Functions on Young Children's Drawing of Familiar and Novel Pictures

Reshaa Alruwaili

Abstract— This study was inspired by previous studies with young children that found (a) that they need both inhibitory control and working memory when drawing an unfamiliar subject (e.g., animals) by adapting their schema of the human figure and (b) that when drawing something familiar (e.g., a person) they use inhibitory control mediated through fine motor control to execute their drawing. This study, therefore, systematically investigated whether direct effects for both working memory and inhibitory control and/or effects mediated through fine motor control existed when drawing both familiar and unfamiliar subjects. Participants were 95 children (41-66 months old) required to draw both a man and a dog, scored respectively for how representational they were and for differences from a human figure. Regression and mediation analyses showed that inhibitory control alone predicted drawing a recognizable man while working memory alone predicted drawing a dog that was not human-like when fine motor control, age, and gender were controlled. Contrasting with some previous studies, these results suggest that the roles of working memory and inhibitory control are sensitive to the familiarity of the drawing task and are not necessarily mediated through fine motor control. Implications for research on drawing development are discussed.

Keywords— child drawing, inhibitory control, working memory, fine motor control, mediation, familiar and unfamiliar subjects.

Self-efficacy and Life Satisfaction among The Post-90s in China

Gao Ya

Abstract—This present study aims to find the relationship between self-efficacy and life satisfaction, and the effect of self-efficacy on life satisfaction among Chinese people whose ages are from 27 to 32, born between 1990 and 1995. People born during this period, despite having received a lot of negative attention and labels at birth, have not received a lot of attention as the subject of academic research. And a great number of research papers mainly study people in individualistic societies. So this specific population whose ages were from 27 to 32, and who lived in a collectivist society, was selected. Demographic information was collected including age, gender, marital status, yearly income and the number of children. The New General Self-efficacy Scale (NGSC) and the Satisfaction with Life Scale (SLS) were used in the questionnaire. A total of 350 questionnaires were distributed in and collected from mainland China, then 261 valid questionnaires were returned in the end, making a response rate of 74.57 per cent. Some statistics techniques were used, like Regression, Correlation, One-Way ANOVA, T-test and general linear model to measure variables. The findings were that self-efficacy positively correlated to life satisfaction and influenced life satisfaction significantly. At the same time, the relationship between demographic information and life satisfaction was analyzed.

Keywords—life satisfaction, marital status, number of children, self-efficacy, yearly income

I. INTRODUCTION

THE post-90s is the population born from 1990 to 1995. According to a Chinese traditional saying: ‘At 30, I had planted my feet firm upon the ground (San Shi Er Li)’, the post-90s, age from 27 to 32, has become the main social power. The post-90s is a typical population in Chinese modern society. First of all, because of the one-child policy then, almost every the post-90s was the only child and was labeled with some negative words, like selfish, irresponsible, etc. Second, experiencing the internet era and big data era, the post-90s witnessed huge transformations in China and the world. These change and progress made them pretty different from their parents' generation on lifestyle and thoughts. Thus, they suffered all kinds of misunderstandings from the parents' generation. Next, due to the impact of globalization, thoughts of the post-90s tended to be more diverse, independent and innovative. Last, the high-speed China's development has created more opportunities and competition, the post-90s is facing unprecedented pressure. This intense stage facilitates the current situation, that is ‘involution’ (Nei Juan). ‘Involution’ means that people pay for too many efforts to compete for limited resources. So the post-90s is the population that not only

has become the main social power but bears a lot of controversies. They should receive more attention as the subject of academic research. Self-efficacy and life satisfaction are important assessment indicators for well-being. Thus, in this ‘involution’ society, studying self-efficacy and life satisfaction of the post -90s is very meaningful. It can be used to measure if this population is satisfied with their current life. This study is not just for an individual to learn how to lead a happy life, it is for the whole society to become more prosperous and harmonious. Although there was a lot of research to study self-efficacy and life satisfaction [6], [16], and more and more researchers started to focus on collectivist counties, like China [14], papers paying attention to the post-90s were rare. To some extent, this study can fill this gap.

Life satisfaction is usually used to measure the quality of life. It is not only an auxiliary effect for life experiences but a crucial indicator for life state as a whole [11]. At the same time, life satisfaction is defined as an overall assessment of an individual's life quality in light of one's personal judgment and criteria for life [2]. Similarly, [13] shows that life satisfaction, as a major component of one's well-being, has been conceptualized to represent and evaluate the general life quality. As an important indicator of life quality, during different life periods, the individuals' life satisfaction always changes over time [4], thus life satisfaction is always used in some specific age groups. Some demographics can be also treated as factors that affect life satisfaction, for example, gender [10], yearly income [7], the number of children [3] and marital status [8].

In terms of [5], self-efficacy is a belief that people believe they have enough abilities to overcome difficulties and achieve higher goals. Reference [5] also presents that self-efficacy is a judgement of capacity. After Bandura proposed the concept of self-efficacy, this concept started to be used widely. Reference [10] shows that there are many factors affect one's life satisfaction, but by controlling other variables, only self-efficacy and perceived health status are related to one's life satisfaction, moreover, self-efficacy is the strongest factor to predict life satisfaction. According to Bandura's Social Cognitive Theory, self-efficacy is a learned human pattern rather than a genetic pattern, it is the product of emotion, life experience, observation and evaluation from others and oneself. Self-efficacy is the result of a life exploring process, people always self-start to shape their life rather than just respond to or receive the environment passively during their lifespan [12]. Like the life satisfaction, self-efficacy also changes over time

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[1]. Reference [15] shows that early adulthood has developed more accuracy in judging their own capacities, so early adulthood has less self-efficacy than adolescents. Therefore, understanding self-efficacy and life satisfaction in a certain life period is very meaningful.

This research has two main objectives:

1. The relationship between self-efficacy and life satisfaction among the post-90s in China;
2. The effect of self-efficacy on life satisfaction among the post-90s in China.

II. METHOD

This research collected data by questionnaires. The questionnaire consisted of 3 parts. The first part was demographic, including 5 items: gender; birth year; yearly income; marital status and the number of children. There were 261 valid participants (male: 44.1%, female: 55.9%). All of the participants were born during 1990-1995. The number of children was respectively '0', '1', '2', '3', but data on 3-children families were not collected. The second part was the New General Self-efficacy Scale (NGSC). The 8-items NGSC was used to measure self-efficacy among the participants. The scale used a 4-point Likert-type format that was as follows: totally incorrect (1), somewhat correct (2), mostly correct (3), completely correct (4). People who got higher scores meant had a stronger self-efficacy (min=11.00, max=40.00, mean=26.969). The third part was the Satisfaction with Life Scale (SLS). The 5-items SLS was used to measure overall life satisfaction among participants. The scale used a 7-point Likert-type format that was as follows: strongly disagree (1), disagree (2), slightly disagree (3), neither agree nor disagree (4), slightly agree (5), agree (6), and strongly agree (7). People who got higher scores meant had a higher level of life satisfaction (min=6.00, max=35.00, mean=24.379).

350 pieces of questionnaires were delivered randomly. Participants confirmed survey content and filled out questionnaires voluntarily. In the end, 261 valid pieces of questionnaires were returned with a response rate of 74.57%. All of data was analyzed with SPSS. All reported P values were double-tailed, $P < 0.05$ was considered statistically significant. Correlation, Regression, One-Way ANOVA, T-test and general linear model were used for measuring variable relationships. Participants' information was confidential during the whole process.

III. DISCUSSION

This research aims to find the effect of self-efficacy on life satisfaction and the relationship between self-efficacy and life satisfaction among the post-90s in China. From statistical results, the TABLE□ and TABLE□ show that self-efficacy significantly influences life satisfaction in the post-90s ($p < 0.001$). Self-efficacy is also a strong predictor of life satisfaction ($R^2 = 0.545$). When an individual's self-efficacy increases, the relative life satisfaction increases, vice versa

($r = 0.738$). This result is consistent with previous studies [10], [12], [14]. Reference [10] also presented that self-efficacy was the strongest factor to predict life satisfaction when other factors were controlled. Nevertheless, some different voices about the relationship between self-efficacy and life satisfaction still existed. Reference [9] showed self-efficacy only had a limited relationship to life satisfaction. Whereas this present research supports the significantly positive correlation between self-efficacy and life satisfaction as well as indicates that self-efficacy has a significant effect on life satisfaction. Moreover, in TABLE□, the mean of self-efficacy is 26.969 (max=40.00), the mean of life satisfaction is 24.378 (max=35.00). That means most of the post-90s in China have a relatively high level of self-efficacy and life satisfaction.

Through T-test and One-Way ANOVA, TABLE□ reveals that gender does not influence life satisfaction significantly in the post-90s ($P = 0.1$). It is same as [11]; TABLE□ reveals that marital status ($F = 7.950$, $P < 0.001$), the number of children ($F = 18.362$, $P < 0.001$) and yearly income ($F = 7.850$, $P < 0.001$) affect life satisfaction significantly. TABLE□ presents that, regarding life satisfaction, married people get higher scores than single people ($r = 0.236$); the family with children has higher scores than the family without children ($r = 0.310$), whereas the number of children does not matter; high yearly income people (above 50,000) has higher scores than low yearly income people (below 50,000) ($r = 0.357$). At the same time, self-efficacy and marital status interactively contribute to life satisfaction significantly ($F = 2.097$, $P = 0.002$).

This present research also has 2 major limitations. On the one hand, other age groups should be included as contrast groups. The contrast group could give evidence for differences among populations who were in different age periods on self-efficacy and life satisfaction. Furthermore, more proofs for change of self-efficacy and life satisfaction during and after transition as well as more details about self-efficacy and life satisfaction in the post-90s could be offered. On the other hand, China has the largest population in the world, there is a large development imbalance among some regions. The collected data have less representation because it is major from south of China.

The present results show satisfying outcomes that the post-90s in China has a good capacity to handle daily life problems and to lead a happy life. Marital plays a role in this results. Although the post-90s is diverse and open, marriage is still an important part of their life.

IV. RESULT

The following content represents results of the study.

TABLE I
STATISTICS

	Self-efficacy	Life satisfaction
N	261	261
Mean	26.9693	24.3793
Std. Deviation	5.88340	6.55845
Variance	34.614	43.013
Range	29.00	29.00
Minimum	11.00	6.00
Maximum	40.00	35.00

TABLE □
THE RELATIONSHIP BETWEEN SELF-EFFICACY AND LIFE SATISFACTION
Dependent Variable: life satisfaction

	B	Std. Error	Beta	t	Sig.
(Constant)	2.180	1.289		1.691	.092
Self-efficacy	.823	.047	.738	17.622	.000

TABLE □
THE EFFECT OF SELF-EFFICACY ON LIFE SATISFACTION
Predictors: self-efficacy

	R	R Square	Adjusted R Square	Std. Error of the Estimate
Self-efficacy	.738 ^a	.545	.543	4.43121

TABLE □
THE EFFECT OF GENDER ON LIFE SATISFACTION
Independent Variable: gender

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Life satisfaction	1.652	259	0.1	1.34652	0.815	-0.25835	2.95138

TABLE □

THE EFFECT AND CORRELATION OF DEMOGRAPHIC ON LIFE SATISFACTION
Dependent Variable:life satisfaction

	Sum of Squares	df	Mean Square	Pearson Correlation	F	Sig. (2-tailed)
yearly income	1749.395	6	291.566	.357**	7.850	.000
marital status	649.200	2	324.600	.236**	7.950	.000
the number of children	1393.479	2	696.740	.310**	18.362	.000
set * marital	958.595	27	35.504		2.097	.002

V. CONCLUSION

The research shows that self-efficacy positively correlates to life satisfaction and influences life satisfaction significantly. Self-efficacy is still an important predictor of life satisfaction. Gender does not make significant differences on life satisfaction. Both male and female can solve social problems effectively and lead a satisfying life that belongs to themselves. However, marital status, the number of children and yearly income influence life satisfaction significantly. There is significant interaction between marital status and self-efficacy on life satisfaction. So owning stable marital status, family relationships and income can enhance one's life satisfaction.

REFERENCES

- [1] Ainscough L, Foulis E, Colthorpe K, et al. Changes in Biology Self-Efficacy during a First-Year University Course. *CBE Life Sciences Education*. 2016 ;15(2). DOI: 10.1187/cbe.15-04-0092. PMID: 27193290; PMCID: PMC4909341.
- [2] Amit, K. (2010). Determinants of Life Satisfaction Among Immigrants from Western Countries and from the FSU in Israel. *Social Indicators Research*, 96(3), 515-534. 10.1007/s11205-009-9490-1
- [3] Angeles, L. (2009). Children and Life Satisfaction. *Journal of Happiness Studies*, 11(4), 523-538. 10.1007/s10902-009-9168-z
- [4] Baird, B. M., Lucas, R. E., & Donnellan, M. B. (2010). Life Satisfaction Across the Lifespan: Findings from Two Nationally Representative Panel Studies. *Social Indicators Research*, 99(2), 183-203. 10.1007/s11205-010-9584-9
- [5] Bandura, A. (2006). Guide for constructing self-efficacy scales. In *Self-Efficacy Beliefs of Adolescents* (pp. 307-337).
- [6] Burger, K., & Samuel, R. (2016). The Role of Perceived Stress and Self-Efficacy in Young People's Life Satisfaction: A Longitudinal Study. *Journal of Youth and Adolescence*, 46(1), 78-90. 10.1007/s10964-016-0608-x
- [7] Chen, J., & Yang, H. (2015). Geographical Mobility, Income, Life Satisfaction and Family Size Preferences: An Empirical Study on Rural Households in Shaanxi and Henan Provinces in China. *Social Indicators Research*, 129(1), 277-290. 10.1007/s11205-015-1102-7
- [8] Figen Kasapoğlu, & Ayşenur Yabanigül. (2018). Marital Satisfaction and Life Satisfaction: The Mediating Effect of Spirituality. *Spiritual Psychology and Counseling*, 3(2), 177-195. <https://doi.org/10.12738/spc.2018.3.2.0048>
- [9] Geraldine O'Sullivan. (2011). The Relationship Between Hope, Eustress, Self-Efficacy, and Life Satisfaction Among Undergraduates. *Social Indicators Research*, 101(1), 155-172. 10.1007/s11205-010-9662-z
- [10] Hampton, N. Z., & Marshall, A. (2000). Culture, Gender, Self-Efficacy, and Life Satisfaction: A Comparison Between Americans and Chinese People with Spinal Cord Injuries. *The Journal of Rehabilitation*, 66(3), 21. <https://search-proquest-com.lingnan.idm.oclc.org/docview/1310704113>
- [11] Huebner, E. S., Suldo, S. M., & Gilman, R. (2006). Life Satisfaction. In G. G. Bear & K. M. Minke (Eds.), *Children's needs III: Development, prevention, and intervention* (pp. 357-368). National Association of School Psychologists.
- [12] Madiha, M., & Akhouri, d. d. (2020). SELF EFFICACY AND LIFE SATISFACTION AMONG YOUNG ADULTS., 2.
- [13] Pavot, W., & Diener, E. (1993). Review of the Satisfaction With Life Scale. *Psychological Assessment*, 5(2), 164-172. 10.1037/1040-3590.5.2.164
- [14] Siu, O., Lu, C., & Spector, P. E. (2007). Employees Well-being in Greater China: The Direct and Moderating Effect of General Self-efficacy. *Applied Psychology*, 56(2), 288-301. 10.1111/j.1464-0597.2006.00255.x
- [15] Vecchio, G. M., Gerbino, M., Pastorelli, C., Del Bove, G., & Caprara, G. V. (2007). Multi-faceted self-efficacy beliefs as predictors of life satisfaction in late adolescence. *Personality and Individual Differences*, 43(7), 1807-1818. 10.1016/j.paid.2007.05.018
- [16] Zhang, R. (2015). Positive Affect and Self-Efficacy as Mediators Between Personality and Life Satisfaction in Chinese College Freshmen. *Journal of Happiness Studies*, 17(5), 2007-2021. 10.1007/s10902-015-9682-0

Quality of Life of Elderly with Vascular Illness and the Level of Depression in 4 Barangays in Malabon, Philippines

Marilou P. Angeles

Abstract— Seniors are a growing number of population all over the world, and they are getting sick with illnesses like diabetes, high blood, and high cholesterol. It is necessary to see the relationship of their physical illness and its effect on their quality of life. Having chronic illnesses also can affect the mood of the elderly; becoming cranky, lonely, not eating, etc. Therefore, there is a need to study the relationship of the quality of life of the elderly and the level of depression. Depression for elderly is known as late onset depression or vascular depression since it is tied to the vascular illnesses they are experiencing, although this is not homogeneous. There is heterogeneity in seniors. The purpose of the study is to determine how keep the satisfaction in life i.e., quality of life of seniors, as long as possible. This study was made in 4 barangays in Longos, Potrero, Tonsuya and Catmon, in Malabon, Metro Manila, Philippines. These Filipino seniors are availing of free medicines for their diabetes, high blood, and high cholesterol ailments in the barangay health centers, given freely by the Department of Health. Two instruments were used; quality of life (CASP-19) and patient health questionnaire (PHQ-19). The quality of life questionnaire was based on the theory of Abraham Maslow, human beings are motivated to action by needs, starting from the lowest, physiological to the highest self-transcendence. Severity of depression is determined by PHQ-9, and according to the unified model of depression by Aaron Beck and Kurt B. Bredemeier, depression happens when a person cannot cope with life has not able to satisfy his needs as a person. The Pearson R correlation was used to determine the significance of the relationship between quality of life and depression. Finding is there is negative relationship between quality of life and depression. It means that a high value of quality of life lowers or minimizes depression. CASP-19 found that the Filipino elderly were in control, independent, enjoying their lives even if they are poor, and this is shown by the significant results. Self-transcendence, a need to give back to others, is important for Filipino elderly. Although the seniors have difficulty with money and they were affected by their illnesses, they are full of optimism, they are ignoring their physical pain because they are focusing on helping their loved ones (i.e., self-transcendence), their children and grandchildren, and if problems come, they are resilient accepting of the challenges, because they have strong faith in God. They are also having pleasures interacting with their friends and neighbors who, like them, have the same health problems. And these two coping strategies for the elderly allow them to live a meaningful life, a life high in quality. Thus, where there is high quality of life, there is none or minimal depression. Recommendation for future study is finding the relationship of spirituality to quality of life of seniors.

Keywords— CASP-19, depression, quality of life, PHQ-9, senior citizen.

The Development of the First Inter-Agency Residential Rehabilitation Service for Gambling Disorder with Complex and Co-Morbid Presentation

Dragos Dragomir, Leon Marsh

Abstract—

Background: As a response to the gaps identified in recent research in the provision of residential care to address co-occurring health needs, including mental health problems and complexities Gordon Moody and Adferiad have developed a new model of care which would extend the GB provision of residential rehabilitation for gambling disorder with complex and co-morbid presentation.

Methodology: The paper outlines our process in the development of a unified approach to recovery-oriented models of care, clinical governance, risk assessment and management and aftercare and continuous recovery. A rapid literature review was conducted to review the current models of care across GB as well as the most recent recommendations for evidence-based treatment for gambling related harm. An intervention mapping approach was used to develop a new model of care for residential services for gambling disorder with complex and co-morbid presentation. This included a thematic analysis of service users and system needs, defining treatment objectives and interventions to meet those objectives, designing and developing the actual interventions and collaboration components of the model and finally, creating adoption, implementation and evaluation plans.

Outcomes: Our collaboration has resulted in the development of the FOLD model which includes three agile and flexible treatment packages aimed at offering the most enhanced and comprehensive treatment in UK, to date, for those most affected by gambling harm. The paper will offer insight into the needs assessment evaluation and the development and implementation of each treatment package.

Conclusion: The FOLD model offers a great opportunity to develop, implement and evaluate a new, much needed, whole-person and whole-system approach to counter gambling related harms. The next phase is to conduct an impact-evaluation of this services.

Keywords—complex needs, gambling disorder, recovery-oriented model of care, residential treatment,

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Search for EEG Correlates of Mental States using EEG Neurofeedback Paradigm

Cyril Kaplan

Abstract— EEG neurofeedback (NF) is commonly researched as a form of treatment for specific symptoms. The principles of closed-loop NF can be harvested in research of mental states too. Throughout a series of studies (n=24), relying on a joined analysis of EEG data and post-session interviews, we developed an experimental paradigm to map introspective correlates of changes in EEG power. As yet, our results show that F3 beta power augments when subjects actively dedicate attention to their surroundings.

Keywords—EEG neurofeedback, states of consciousness, frontal beta activity, mixed methods

Individuals' Inner Wellbeing during the COVID-19 Pandemic: A Quantitative Comparison of Social Connections and Close Relationships between the UK and India

Maria Spanoudaki, Pauldy C. J. Otermans

Abstract— Relationships form an integral part of everyday wellbeing. This study focuses on Inner Wellbeing, which can be described as individuals' thoughts and feelings about what they can do and be, and the purpose is to compare the Social Connections and Close Relationship dimensions of Inner Wellbeing during COVID-19 between the UK and India. 392 UK and 205 Indian participants completed the Inner Wellbeing scale. Results showed that Social Connections were significantly lower during COVID-19 in the UK compared to India, whereas there is no significant difference for Close Relationships.

Keywords— close relationships, COVID-19 pandemic, social connections, wellbeing.

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Co-produced Databank of Tailored Messages to Support Engagement to Digital Health Interventions

Menna Brown, Tania Domun

Abstract— Digital health interventions are effective across a wide array of health conditions spanning physical health, lifestyle behaviour change, and mental health and wellbeing; furthermore, they are rapidly increasing in volume within both the academic literature and society as commercial apps continue to proliferate the digital health market. However, adherence and engagement to digital health interventions remains problematic. Technology-based personalised and tailored reminder strategies can support engagement to digital health interventions. Interventions which support individuals' mental health and wellbeing are of critical importance in the wake of the COVID-19 pandemic. Student and young person's mental health has been negatively affected and digital resources continue to offer cost effective means to address wellbeing at a population level. Develop a databank of digital co-produced tailored messages to support engagement to a range of digital health interventions including those focused on mental health and wellbeing, and lifestyle behaviour change. Qualitative research design. Participants discussed their views of health and wellbeing, engagement and adherence to digital health interventions focused around a 12-week wellbeing intervention via a series of focus group discussions. They worked together to co-create content following a participatory design approach. Three focus group discussions were facilitated with (n=15) undergraduate students at one Welsh university to provide an empirically derived, co-produced, databank of (n=145) tailored messages. Messages were explored and categorised thematically, and the following ten themes emerged: Autonomy, Recognition, Guidance, Community, Acceptance, Responsibility, Encouragement, Compassion, Impact and Ease. The findings provide empirically derived, co-produced tailored messages. These have been made available for use, via 'ACTivate your wellbeing' a digital, automated, 12-week health and wellbeing intervention programme, based on acceptance and commitment therapy (ACT). The purpose of which is to support future research to evaluate the impact of thematically categorised tailored messages on engagement and adherence to digital health interventions.

Keywords— digital health, engagement, wellbeing, participatory design, positive psychology, co-production.

Political Polarization May Be Distorted When It Comes to Police Reform

Nancy Bartekian, Christine Reyna

Abstract— Republicans and Democrats are often polarized when it comes to important topics, but the portrayal of polarization of key issues might be distorted and exaggerated. We examined Republicans' and Democrats' attitudes about police reform policy during the 2020 racial justice protests and calls to 'defund the police'. We hypothesized that a) Republicans and Democrats will be polarized on the "defund police" question; however, b) they will have similar overall attitudes towards specific police reform policies (will be on the same side of the scale--disagree vs. agree), but c) will differ in their extent of agreement or disagreement (main effect of political party ID, but located on the same side of the scale). Using one-way, Multivariate analysis of covariance (MANCOVA) controlling for race, education, and income, we found an overall effect of political party ID. Six out of the nine policies studied were, in fact, not polarizing; both groups were in consensus on whether they disagreed or agreed with the policy, including "defund police". Results suggest that polarization might be exaggerated.

Keywords— political psychology, social, ideology, polarization.

The Need for a Cultural Transformation Toward Wellbeing

- A Theoretical Exploration

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Abstract— There is a universal contradiction among the public that has long been observed, but unsolved, by scholars of positive psychology: while individuals may agree with the notion that “money does not buy happiness,” when surveyed about what would improve the quality of their lives, the foremost answer was “more money”.

In his essay, “If We Are So Rich, Why Aren’t We Happy?”, the “grandfather of positive psychology”, Dr. Mihaly Csikszentmihalyi, noted: “Despite the evidence that the relationship between material wealth and happiness is tenuous at best, most people still cling to the notion that their problems would be resolved if they only had more money.”

This, then, is a widespread and deep-rooted, therefore cultural, illusion that money is the route to happiness, as evidence shows that money’s effect on happiness starts diminishing after basic needs are met, as is the case for most people in developed countries.

The consequences of this illusion are multiple and multiplying: A society full of people devoting their lives to chasing after material wealth, often without achieving actual happiness or wellbeing; a pervasive “keeping up with the Joneses” mentality; stress from competing for financial success and related mental health issues, excessive material possession and consumption driving market demand and unnecessary production; national policies that assume endless economic growth, depleting natural resources and damaging the environment; divisions among socioeconomic groups, etc. This cultural illusion lies at the root of the “hot” issues of the day – our environmental crisis, political polarization, soaring inequality and widespread resentment, and even international conflicts.

If, as abundant evidence has established, our whole society’s zest for pursuing “more money” does not necessarily lead to more happiness and wellbeing, but does necessarily lead to serious social problems, to achieve societal wellbeing, then, first requires people collectively wake up from the cultural illusion and learn to pursue authentic happiness and wellbeing instead.

In short, our society needs a cultural transformation from pursuing material wealth to pursuing wellbeing.

This cultural transformation is not about eliminating capitalism. Nor can it resort to a top-down change, because, as the author will explore, the illusion is not a top-down phenomenon. Without correcting the cultural idea of money as the route to happiness at the individual level, the thirst for material possessions will continue as a social norm to fuel excessive market demand, incentivizing wasteful production. The illusion also will continue generating the society-wide desire for perpetual growth of personal wealth,

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incentivizing local, national, and global policies to pursue unlimited economic growth, often at the expense of social and environmental wellbeing.

Carl Jung observed, “[Collective] problems are never solved by legislation or tricks. They are only solved by a general change of attitude. And the change...begins with a change in individuals.”

A general change of attitude in individuals across society – i.e. a cultural transformation away from pursuing wealth and toward pursuing wellbeing – seems an essential grand undertaking in which we in positive psychology may take an important role. Methods to promote such a cultural transformation will be explored.

Keywords— wellbeing, happiness, social transformation, wealth, money, cultural illusion

References

Campbell, A. (1981). *The sense of well-being in America*. New York: McGraw-Hill.

Csikszentmihalyi, M. (1999). If we are so rich, why aren't we happy? *American Psychologist* 54(10), 821-827.

Jung, C, (1940). *Psychology and Religion*. Zurich

An Inflammatory Mediated Hypothesis of COVID-19 Psychosis

Hilary P. Stevenson, MD, PhD, Alexander J. Hayek, DO, Amie Dereczyk, MD

Abstract— In this case report, we provide an example of an asymptomatic COVID-19 positive patient who presented with new-onset psychosis with severe paranoid delusions. He was seen in our ED after ingesting isopropyl alcohol which he reported was an attempt to escape presumed attackers, which at the time was logical to the patient. The patient's family had COVID-19 symptoms that corresponded to those typically observed from the Omicron variant. The patient was treated successfully, within ten days, with Risperdal twice-daily dosing resulting in the resolution of the patient's delusions and improved insight regarding the events that led to his hospitalization. In this work, we examine possible contributing factors to new-onset psychosis in the context of COVID-19, a phenomenon that is becoming increasingly notable in the literature. One area of importance is the already established inflammatory hypothesis of psychosis in which defects in the innate immune system, which result in its overactivation, may play a role in a typical first-episode psychosis, in addition to subsequent episodes. Given that COVID-19 is known to cause derangements in the innate immune system, such as cytokine storm reactions, this link may be critical in further understanding the etiologies of new-onset COVID-19 psychosis and its risk factors. Also included in this work is a brief review of antipsychotic interventions that have been described in the literature to date for the first episode of COVID-19-related psychosis. This will explore the potential of some antipsychotics to innately diminish the production of pro-inflammatory cytokines, further enhancing their usefulness in COVID-19 first-episode psychosis patients.

Keywords—Covid-19, first break psychosis, inflammatory hypothesis of psychosis,

The effect of cultural tightness-looseness on tourism destination choice for Western Europeans: Evidence from Saudi Arabia

Faisal Alsubaie

Abstract— This study addresses the question: How do the changes in cultural tightness–looseness (CTL) influence the perceptions of Western European tourists and their willingness to visit Saudi Arabia (SA)? To answer this research question, the study adopts a research design of two phases sequential mixed method; (1) first phase employs a quantitative survey to measurement the tourists' perceptions of the recent changes in cultural tightness (i.e., the strength of cultural norms and tolerance for deviant behaviour) and their impacts on their intention to visit SA. (2) the second phase employs qualitative semi-structured interviews to get an in-depth explanation of the findings of the first phase of the study. This study contributes to the literature by developing a framework using CTL theory to investigate the effects of CTL on tourism destination choice in a Saudi context which has not been examined before.

Keywords— Tourism Management, Saudi Arabia, Cultural tightness looseness, social norms, Western European.

Toxicities associated with EBRT and Brachytherapy for Intermediate and High Risk Prostate Cancer, Correlated with Intra-operative Dosing

Rebecca Dunne, Cormac Small, Geraldine O'Boyle, Nazir Ibrahim, Anisha

Abstract— Prostate cancer is the most common cancer among men, excluding non-melanoma skin cancers. It is estimated that approximately 12% of men will develop prostate cancer during their lifetime. Patients with intermediate, high risk, and very-high risk prostate cancer often undergo a combination of radiation treatments. These treatments include external beam radiotherapy with a low-dose rate or high-dose rate brachytherapy boost, often with concomitant androgen deprivation therapy. The literature on follow-up of patients that receive brachytherapy is scarce, particularly follow-up of patients that undergo high-dose rate brachytherapy. This retrospective study aims to investigate the biochemical failure and toxicities associated with triple therapy and external beam radiotherapy given in combination with brachytherapy. Reported toxicities and prostate specific antigen (PSA) were retrospectively evaluated in eighty patients that previously underwent external beam radiotherapy with a low-dose rate or high dose-rate brachytherapy boost. The severity of toxicities were correlated with intra-operative dosing during brachytherapy on ultrasound and CT scan. The results of this study will provide further information for clinicians and patients when considering treatment options.

Keywords— toxicities, combination, brachytherapy, intra-operative dosing, biochemical failure.

Prenatal Genetic Screening and Counselling Competency Challenges of Nurse-Midwife

Girija Madhavanprabhakaran, Frincy Franacis, Sheeba Elizabeth John

Abstract— Introduction: A wide range of prenatal genetic screening is introduced with increasing incidences of congenital anomalies even in low-risk pregnancies and is an emerging standard of care. Being frontline caretakers, the role and responsibilities of nurses and midwives are critical as they are working along with couples to provide evidence-based supportive educative care. The increasing genetic disorders and advances in prenatal genetic screening with limited genetic counselling facilities urge nurses and midwifery nurses with essential competencies to help couples to take informed decision. Objective: This integrative literature review aimed to explore nurse midwives' knowledge and role in prenatal screening and genetic counselling competency and the challenges faced by them to cater to all pregnant women to empower their autonomy in decision making and ensuring psychological comfort. Method: An electronic search using keywords prenatal screening, genetic counselling, prenatal counselling, nurse midwife, nursing education, genetics, and genomics were done in the PUBMED, SCOPUS and Medline, Google Scholar. Finally, based on inclusion criteria, 8 relevant articles were included. Results: The main review results suggest that nurses and midwives lack essential support, knowledge, or confidence to be able to provide genetic counselling and help the couples ethically to ensure client autonomy and decision making. The majority of nurses and midwives reported inadequate levels of knowledge on genetic screening and their roles in obtaining family history, pedigrees, and providing genetic information for an affected client or high-risk families. The deficiency of well-recognized and influential clinical academic midwives in midwifery practice is also reported. Evidence recommended to update and provide sound educational training to improve nurse-midwife competence and confidence. Conclusion: Overcoming the challenges to achieving informed choices about fetal anomaly screening globally is a major concern. Lack of adequate knowledge and counselling competency, communication insufficiency, need for education and policy are major areas to address. Prenatal nurses' and midwives' knowledge on prenatal genetic screening and essential counselling competencies can ensure services to the majority of pregnant women around the globe to be better-informed decision-makers and enhances their autonomy, and reduces ethical dilemmas.

Keywords— challenges, genetic counselling, prenatal screening, prenatal counselling.

Three or Four Tonics and a Wave: The Trajectory of Health Insurance Regulation in Brazil

João Boaventura Branco De Matos

Abstract— Currently, in Brazil, there is a considerable collection of publications on the supplementary health sector, but the vast majority is limited to retrospective examination of the sector. The present contribution starts from the diagnosis of an overwhelming change in the role of the State and its institutions, as well as an accelerated and no less forceful change in the way of producing goods and services, resulting in a clash between these different waves (state and market). This shock produces unique energy, capable of imposing major changes in the most varied sectors. Based on this diagnosis, there was an opportunity to offer the perspective and propositional study of regulatory measures relevant to the best conduct and performance of this sector in the future.

Keywords— private health regulation, state and market, forecasts in Brazilian regulation, political economy.

The Osteocutaneous Distal Tibia Turn-over Fillet Flap: A Novel Spare-parts Orthoplastic Surgery Option for Functional Below-knee Amputation

Harry Burton, Alexios Dimitrios Iliadis, Neil Jones, Aaron Saini, Nicola Bystrzonowski, Alexandros Vris, Georgios Pafitanis

Abstract— This article portrays the authors' experience with a complex lower limb bone and soft tissue defect, following chronic osteomyelitis and pathological fracture, which was managed by the multidisciplinary orthoplastic team. The decision for functional amputation versus limb salvage was deemed necessary, enhanced by the principles of "spares parts" in reconstructive microsurgery. This case describes a successful use of the osteocutaneous distal tibia turn-over fillet flap that allowed 'lowering the level of the amputation' from a through knee to the conventional level of a below-knee amputation to preserve the knee joint function. This case demonstrates the value of 'spare-parts' surgery principles and how these concepts refine complex orthoplastic approaches when limb salvage is not possible to enhance function. The osteocutaneous distal tibia turn-over fillet flap is a robust technique for modified BKA reconstructions that provides sufficient bone length to achieve a tough, sensate stump and functional knee joint.

Keywords— osteocutaneous flap, fillet flap, spare-parts surgery, Below knee amputation.

Awareness of Telerehabilitation as Related to Its Implementation and Barriers Among Indian Optometrists

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ABSTRACT

Purpose: The purpose of this study was to assess the awareness, practice experience, technical quality and perceived barriers to implementation of telerehabilitation into the current practice of Indian optometrists.

Methods: The study was conducted using the focused group discussion method in order to find out the different perspective of individuals .Qualitative approach was considered for the collection and analysis of data. Focused group discussion was conducted in department of optometry SRIHER during the time frame of Jan 2021.A focused group discussion guide was prepared in order to address necessary questions to the participants and was completely based on research questions of the study. Questionnaire made as per focused group discussion was sent to experts in the field and as per their recommendations final questionnaire was made The participants included in the study were selected based on inclusion criteria and officially contacted through mail id's. They were then segregated into two groups based on their

awareness in providing telerehabilitation.. SPSS version 16 was used to do data analysis. An online survey was conducted among PAN India optometric practitioners using Google forms. 196 respondents provided information regarding their interest in telerehabilitation for low vision patients.

Results: Of the 196 participants 54.3% were females and the rest 45.7% were males, and 85.2% were less than thirty years of age. 79.2% of the participants were optometry practitioners of which 11.2% of them had greater than ten years of experience in the field of low vision care. Awareness about telerehabilitation was noted among 70.9% (n=139) of the participants however only 87.9% of them have practiced telerehabilitation. 98.5% of these practitioners felt that more awareness has to be created. 21.9% still project unperceived blocks in providing telerehabilitation.

Conclusion: This study states that practitioners possess adequate knowledge about telerehabilitation in low vision however lack of technical assistance, man power, and proper infrastructure restricts them from practicing it routinely. These results highlight the necessity to improve technical knowledge, legal rules to implement telerehabilitation in to the practice for low vision.

Keywords: Awareness, Low vision, Rehabilitation, Technical knowledge, Telerehabilitation.

1. INTRODUCTION:

During the times of crisis like covid-19 many have faced mental and emotional imbalances. For a person with low vision as he already goes through these stages it is difficult to cope up with individuals in such times the need for rehabilitation will be more. As situations do not support to walk in person telerehabilitation play a major role. Every low vision individual for a short or long span have undergone

- physical and functional measures (e.g. activities of daily living, mobility and orientation, reading);
- psychological measures (e.g. depression, mood, anxiety, adaptation to vision loss, self-esteem);
- social measures ([van Nispen et al., 2020](#)) (e.g. loneliness or independence).

Thus, a trained rehabilitation can take care of those people emotional needs.

The clinical services offered to low vision may include orientation and mobility training, training to utilize and use assistive technology, occupational therapy services, social work services, work support services and rehabilitation services. Low vision rehabilitation ([Brennan et al., 2004](#)) uses strategies that maximizes or substitute for the lost sight supporting independence and a way of self-worth.

Low vision rehabilitation can improve reading ability function for visually impaired individuals ([Binns et al., 2012](#)) but it's effectiveness depends on applying appropriate rehabilitation techniques, skill reinforcement with correct magnification devices, patient motivation, and compliance ([Stelmack et al., 2017](#))

The study aims to know the knowledge, awareness, and perception (KAP) of practitioners about telerehabilitation so that the gap can be bridged.

2.METHODOLOGY:

The study was conducted using the focused group discussion method in order to find out the different perspective of individuals .Qualitative approach was considered for the collection and analysis of data. The participants included in the study were selected based on inclusion criteria and officially contacted through mail id's. They were then segregated into two groups based on their awareness in providing telerehabilitation. Focused group discussion was conducted in department of optometry SRIHER during the time frame of Jan 2021.A focused group discussion guide was prepared in order to address necessary questions to the participants and was completely based on research questions of the study. SPSS version 16 was used to do data analysis.

RESULTS:

One hundred and ninety-six low vision practitioners across India participated in this study. Of the 196 participants 54.3% were females and the rest 45.7% were males. The years of experience varied among the participants and nearly 14.2% of the participants were over thirty years of age and 11.2 % of them had greater than ten years of experience. Nearly one third of the participants were from Tamilnadu, followed by Andhra Pradesh and Karnataka. Among the participants 79.2% were optometry practitioners and 8.1% were ophthalmologist. Others included post graduate students of optometry and ophthalmology. Detailed demographic details of the participants are as shown in Table 5.1.

Table 1: Demographic details of the participants

Variables	Number (%)
Gender	
Female	108(55.1)
Male	88(44.9)
Age in years	
Less than 30	167(85.2)
30-40	20(10.2)
40-50	6(3)
More than 50	2(1)
Years of experience	
Less than 10	175(88.8)
10-15	14(7.1)
15-20	5(2.5)
More than 20	3(1.5)
Region of practice	
Tamilnadu	62(31.5)
Andhra Pradesh	31(15.7)
Karnataka	25(12.7)
Odisha	19(9.6)
Others	60(30.1)

AWARENESS:

With regards to the awareness on telerehabilitation of the 196 participants only 139 (70.9%) were aware of telerehabilitation for low vision. Of the 66 of them have provided telerehabilitation .Among them 58 (87.9%) are comfortable in providing telerehabilitation. Among the providers 51.5% of them feel that the technical quality consultation is excellent, only 10.6% faces technical glitches.

As far as the overall effectiveness of telerehabilitation was considered 45.5% felt it gave excellent outcomes. Further more 50 % of the practitioners who are currently providing telerehabilitation for low vision felt that the quality of care was excellent compared to traditional low vision care provided.

A detailed description of the technical quality, overall effectiveness and the quality of care delivered are depicted in fig 5.1

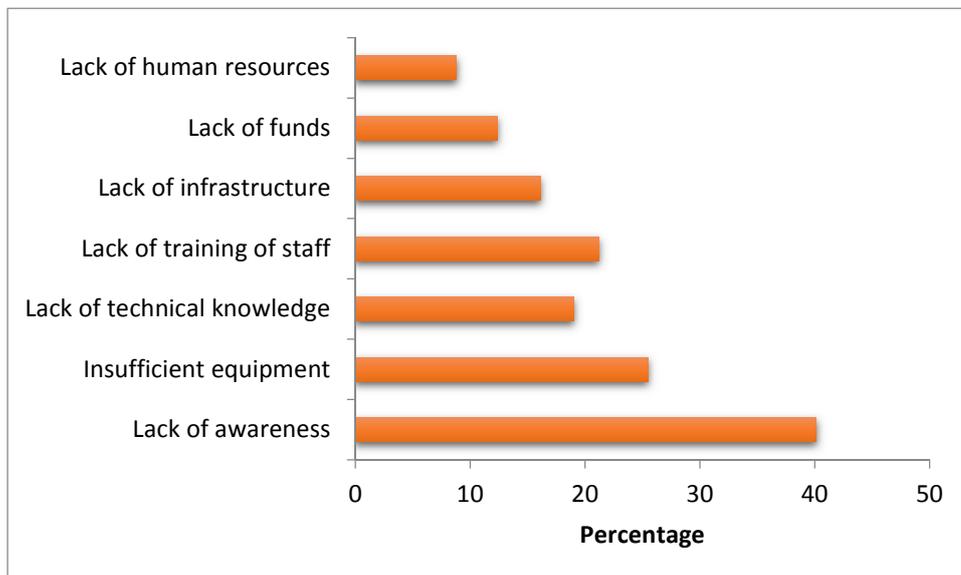


FIG:5.1 Description of the technical quality, overall effectiveness and the quality of care delivered.

55.1% of the providers were highly satisfied with the outcome.98.5% of them felt that more awareness has to be created and 93.9% also felt that the telerehabilitation can have a positive impact on the quality of life of patients with low vision.77.3% felt more awareness should be created on the legal policies of the telerehabilitation. However, 78.8% of the practitioners felt telerehabilitation may pose economic burden on patients compared to traditional rehabilitation. A detailed description of the said criteria are depicted on fig 5.2

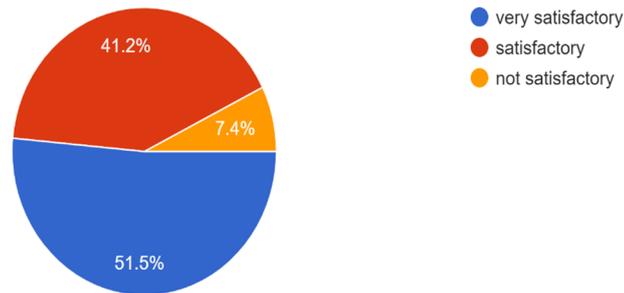


FIG 5.2: Need for awareness ,Legal policies and Economic burden

WILLINGNESS AND CHALLENGES:

Among those who were not providing telerehabilitation (N=73) though they were aware of it, 98.6%also insisted that telerehabilitation can be implemented only if necessary technical trainings were provided.21.9% still project unperceived blocks in providing low vision telerehabilitation.

However, 90.4% also felt that telerehabilitation would be a challenging option. The various challenges perceived in implementing telerehabilitation were depicted in fig 5.3

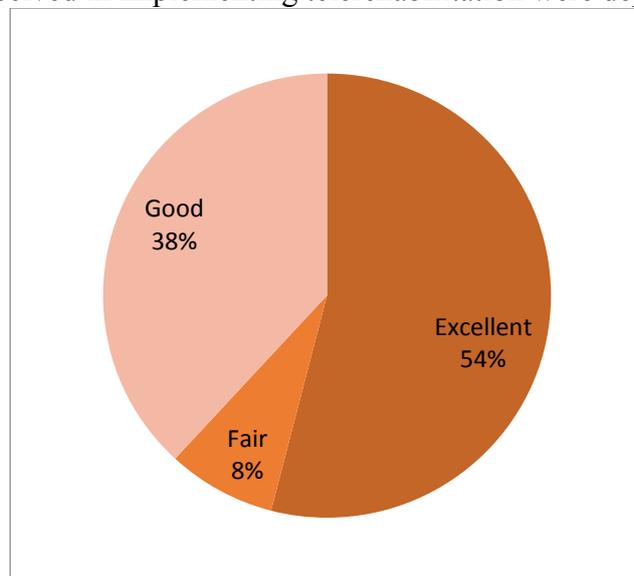


FIG:5.3 Various challenges perceived in implementing telerehabilitation

DISCUSSION:

The current study elicited the awareness, knowledge and experience of Indian practitioners in providing telerehabilitation to low vision subjects. Though practitioner attitudes towards telerehabilitation have been documented across various faculties, this is the first of its kind to

have been completed by Indian optometrists. The significance of this study lies on its participants being practitioners across the nation being facilitated by conducting a web based survey.

Only a small group of participants (37.2%) were unaware of telerehabilitation in current study as against the majority of the participants (86.1%) being unaware of telerehabilitation in ferris et al study(Ferris & Tielsch, 2004) . Even after being aware of telerehabilitation 45.2% has not given telerehabilitation at any point of time in their practice. This implies that awareness alone is not important to implement telerehabilitation into one's practice.

Various challenges in implementing telerehabilitation were also identified and the perceptions of the respondents on those challenges were also elicited. Only 53.3% of the respondents were willing to incorporate telerehabilitation into their service provided technical supports are extended whereas in another study 97.5% were interested in providing telerehabilitation if specific infrastructure is provided

This shows awareness was improved a lot but still needs to remove barriers to implement. Lack of awareness, insufficient equipment, lack of technical knowledge, lack of training to staff, lack of infrastructure, lack of funds, lack of human resource are all the challenges preventing the implementation of telerehabilitation into routine practice.

Conclusion :

This is the first study to report the knowledge, awareness and drawbacks with respect to telerehabilitation for low vision among eye care practitioners in India. Even when all other means of delivering low vision services are challenged especially during times like the COVID-19 pandemic, telerehabilitation can support delivering quality eye care services. Upgrading the existing infrastructure, training the staffs accordingly, increasing the manpower and instigating legal policies can support the implementation of telerehabilitation for low vision subjects across the nation. Hoping that this study fills the gap and identifies the barriers further research on these lines can improve the effectiveness of low vision care.

REFERENCES:

- Binns, A. M., Bunce, C., Dickinson, C., Harper, R., Tudor-Edwards, R., Woodhouse, M., Linck, P., Suttie, A., Jackson, J., Lindsay, J., Wolffsohn, J., Hughes, L., & Margrain, T. H. (2012). How effective is low vision service provision? A systematic review. *Survey of Ophthalmology*, 57(1), 34–65.
- Brennan, D. M., Georgeadis, A. C., Baron, C. R., & Barker, L. M. (2004). The effect of videoconference-based telerehabilitation on story retelling performance by brain-injured subjects and its implications for remote speech-language therapy. *Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association*, 10(2), 147–154.

Ferris, F. L., 3rd, & Tielsch, J. M. (2004). Blindness and visual impairment: a public health issue for the future as well as today. *Archives of Ophthalmology*, 122(4), 451–452.

Stelmack, J. A., Charlene Tang, X., Wei, Y., Wilcox, D. T., Morand, T., Brahm, K., Sayers, S., Massof, R. W., & for the LOVIT II Study Group. (2017). Outcomes of the Veterans Affairs Low Vision Intervention Trial II (LOVIT II). In *JAMA Ophthalmology* (Vol. 135, Issue 2, p. 96). <https://doi.org/10.1001/jamaophthalmol.2016.4742>

van Nispen, R. M. A., Virgili, G., Hoeben, M., Langelaan, M., Klevering, J., Keunen, J. E. E., & van Rens, G. H. (2020). Low vision rehabilitation for better quality of life in visually impaired adults. In *Cochrane Database of Systematic Reviews*. <https://doi.org/10.1002/14651858.cd006543.pub2>

The Prevalence of Herbal Medicine Practice and Associated Factors among Cancer Patients Receiving Palliative Care at Mobile Hospice Mbarara

Harriet Nalubega, Eddie Mwebesa

Abstract— In Uganda, over 90% of people use herbal remedies. Herbal medicine use has been associated with delayed clinical appointments, presentation with advanced cancers, financial constraints, and misdiagnosis. This study aimed to evaluate the prevalence of herbal medicine use and practices amongst cancer patients receiving Palliative Care at Mobile Hospice Mbarara (MHM) and the associated challenges. This was a mixed-methods prospective study conducted in 2022 at MHM, where patients were interviewed, and a questionnaire was completed. 87% of the patients had used herbal medicine. Of these, 83% were female, and 59% had not received formal education. 27% of patients had used herbal remedies for a year or more. 51% of patients who were consuming herbs stopped using them after starting palliative care treatment. Motivations for herbal medicine use were in the hope for a cure in 59%, for pain relief in 30%, and peer influence in 10%. There is a high prevalence of herbal medicine use in Palliative Care. Female gender and lack of formal education were disproportionately associated with herbal remedy use. Most patients consume herbal remedies in search of a cure or to relieve severe pain. Education of cancer patients about herbal remedy use may improve treatment outcomes in Palliative Care.

Keywords— prevalence, herbal medicine, cancer patients, palliative care.

Disordered Eating Behaviors Among Sorority Women

Andrea J. Kirk-Jenkins

Abstract— Women in late adolescence and young adulthood are particularly vulnerable to disordered eating, and prior research indicates that those within the college and sorority communities may be especially susceptible. Research has primarily involved comparing eating disorder symptoms between sorority women and non-sorority members using formal eating disorder assessments. This phenomenological study examined sorority members' (N = 10) perceptions of and lived experiences with various disordered eating behaviors within the sorority culture. Data from individual interviews and photographs indicated two structural themes and 11 textural themes related to factors associated with disordered eating behaviors. These findings point to the existence of both positive and negative aspects of sorority culture, normalization of disordered eating behaviors, and pressure to attain or maintain an ideal body image. Implications for university stakeholders, including college counselors, health center staff, and extracurricular program leaders, are discussed. Further research on the identified textural themes as well as a longitudinal study exploring how perceptions change from rush to alumnae status is suggested.

Keywords— eating disorders, disorder eating behaviors, sorority women, sorority culture, college women.

An Exploration of the Emergency Staff's Perceptions and Experiences of Teamwork and the Skills required in the Emergency Department in the Northern Border Province of Saudi Arabia

Sami Alanazi

Abstract— Background: Teamwork practices have been recognized as a significant strategy to improve patient safety, quality of care, and staff and patient satisfaction in healthcare settings, particularly within the emergency department (ED). The EDs depend heavily on teams of interdisciplinary healthcare staff to carry out their operational goals and core business of providing care to the serious illness and injured. The ED is also recognized as a high-risk area in relation to service demand and potential for human error. Few studies have considered the perceptions and experiences of the ED staff (physicians, nurses, allied health professionals, and administration staff) about the practice of teamwork, especially in Saudi Arabia (SA), and no studies have been conducted to explore the practices of teamwork in the EDs.

Aim: To explore the practices of teamwork from the perspectives and experiences of staff (physicians, nurses, allied health professionals, and administration staff) when interacting with each other in the admission areas in the ED of a public hospital in the Northern Border region of SA.

Method: A qualitative case study design was utilized, drawing on two methods for the data collection, comprising of semi-structured interviews (n=22) with physicians (6), nurses (10), allied health professionals (3), and administrative members (3) working in the ED of a hospital in the Northern Border region of SA. The second method is non-participant direct observation. All data were analyzed using thematic analysis.

Findings: The main themes that emerged from the analysis were as follows: the meaningful of teamwork, reasons of teamwork, the ED environmental factors, the organizational factors, the value of communication, leadership, teamwork skills in the ED, team members' behaviors, multicultural teamwork, and patients and families behaviors theme.

Discussion: Working in the ED environment played a major role in affecting work performance as well as team dynamics.

However, Communication, time management, fast-paced performance, multitasking, motivation, leadership, and stress management were highlighted by the participants as fundamental skills that have a major impact on team members and patients in the ED. It was found that the behaviors of the team members impacted the team dynamics as well as ED health services. Behaviors such as disputes among team members, conflict, cooperation, uncooperative members, neglect, and emotions of the members. Besides that, the behaviors of the patients and their accompanies had a direct impact on the team and the quality of the services. In addition, the differences in the cultures have separated the team members and created undesirable gaps such the gender segregation, national origin discrimination, and similarity and different of interests.

Conclusion: Effective teamwork, in the context of the emergency department was recognized as an essential element to obtain the quality of care as well as improve staff satisfaction.

Keywords— Emergency Department, Teamwork, Barrier, Facilitator, Saudi Arabia

Evaluation of the Nutritional Potential of a Developed Spice Formulation for nah poh (An Emulsion-Based Gravy): Physicochemical and Techno-Functional Characterisations

Djiazet Stève, Mezajoug Kenfack Laurette Blandine, Ravi Pullakhandam, Bethala L. A. Prabhavathi Devi, Tchiegang Clergé, Prathapakumar Halady Shetty

Abstract— The nutritional potential of a developed spice formulation for nah poh was evaluated. It was found that when spices were used for the formulation for nah poh, the concentration of some nutrients is diluted while that of some of them increases. The proportion of unsaturated fats was estimated to be 76.2% of the total fat content while the chemical score varied between 31 to 39%. The contents of some essential minerals of nutritional interest in mg are as follows for 100g of spice: 2372.474 ± 0.007 for potassium, 16.447 ± 0.010 for iron, 4.772 ± 0.005 for zinc, 0.537 ± 0.001 for copper, 0.138 ± 0.005 for selenium, and 112.954 ± 0.003 for manganese. This study shows that the consumption of these spices in the form of formulation significantly contributes to meet the mineral requirements of the populations whose food habits regularly require these spices.

Keywords— spice formulation, characterisation, nutritional potential, nah poh, techno functional properties.

Undernutrition and Management Outcomes of Hospitalized Children Before and after 2015 Armed Crisis in Aden

Aidroos Zain Bukair, Aida Hussein Mohammed Alsadeeq, Huda Omer Basaleem

Abstract— Introduction: In 2015, Yemen spiraled into armed crisis and the ongoing fighting, which has been dating back to 2011 with low level of conflict, has escalated and pushing Yemen to the brink of famine. The study aimed to describe the pattern of undernutrition and outcome indicators among hospitalized children during three time periods: 2010 (before the 2011 revolution), 2014 and 2016 (before and after 2015-armed crisis). Methods: This is a retrospective observational study used data generated from registry records of Severe Acute Malnourished (SAM) children admitted in the Therapeutic Feeding Centers (TFC) of Al-Sadaka General Teaching Hospital, Aden. Variables included were age, gender, address, weight (kg), length/height (cm), mid-upper arm circumference (cm), presence of bilateral pitting edema, standard deviation of weight for height, weight for age, height for age, and management outcomes (recovery, death, defaulter, and transfer out & medical transfer).

Result: A total of 803 new complicated SAM patients were included in the study, of which 22.7%, 32.0%, and 45.3% were admitted during 2010, 2014, and 2016 respectively. Compared to 2010, the frequency of severe wasting, underweight, and stunting were significantly high in 2016. There was no significant gender difference. The majority of children were from Shikh Othman and Dar Sa'ad districts. Increasing percentages of patient in 2016 found from Altawahi, Almualla, Khoumakser districts, which were the scene of armed clashes during 2015. Poor outcome indicators were noted during 2016.

Conclusion: Poor nutritional and outcome indicators were encountered after the 2015-armed crisis. It is incumbent on pediatricians, public health professionals, and policy makers to seriously address undernutrition in the context of conflict as critical and priority issue. Children must be counted.

Keywords— conflict, sam, outcome indicators, Yemen.

How Do Overweight People Dropout Of a Weight Loss Diet? A Qualitive Study

M.A Choobineh. L Bazrafkan. M.H Sharifi. M Farid

Abstract— Background

The growing trend of overweight and obesity in many developed and developing countries in recent years has made obesity one of the most significant health problems in the world. The treatment of overweight and obese people is challenging, as patients have difficulty adhering to a weight-loss diet. Thus, the present study aimed to identify the reasons for the dropout of weight-loss diets.

Methods

This qualitative study using content analysis was conducted in a comprehensive health center in Shiraz, southern Iran. The study was performed on 27 participants with a history of obesity and diet dropout selected via purposive and theoretical sampling. The data were gathered through semi-structured interviews and were thematically analyzed.

Results

The participants included 25 females (92.6%) and two males (7.4%) with a mean age of 33.4 ± 8.4 years. Data analysis resulted in the emergence of three themes and 14 sub-themes. The first theme was personal reasons for diet dropout, which included six sub-themes; i.e., misunderstanding of diet, not having enough motivation, stress and hormonal disorder, having the feel of “being harmful to health”, lack of mental and psychological preparation, and personal taste. The second theme was familial and social reasons for diet dropout, including two sub-themes, i.e., social and familial problems. Finally, the third theme was the reasons related to diet characteristics, including six sub-themes: ineffectiveness of diet, expensiveness of diet food and dietary supplements, family problems, unavailability of food, unscientific and unconventional diets feeling bad about the diet, and unpalatable diet food. All the concepts were related to each other and resulted in a pattern revealing the experiences of overweight people and who had dropped out of weight-loss diets.

Conclusion

The reasons for diet dropout were divided into three levels: personal reasons, familial and social reasons, and diet characteristics. Overall, clinicians should pay attention to the complexity of diets to increase the success rate of weight management. Based on the current study findings, a guideline is recommended to guide patients who dropout of weight-loss diets.

Keywords— dropout, overweight, weight loss diet, qualitative study.

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Focusing a Gender Lens on Household Food Security among Vulnerable Lake Kariba Fisher Families: Household Hunger Scale II Results

Kathleen Ragsdale, Mary Read-Wahidi, Netsayi Mudege, Pamela Marinda, Robert Kolbila

Abstract— In low- and middle-income countries (LMIC) across sub-Saharan Africa – including Zambia – an estimated that 250 million children under five years of age are at developmental risk due to extreme poverty, which can manifest as wasting (low weight-for-height), stunting (low height-for-age) or hidden hunger (chronic deficiencies in multiple essential micronutrients due to diets that are of insufficient quality).[1][2] For example, Zambia has high rates of food insecurity and childhood malnutrition and ranks 139th among 162 countries in meeting the Sustainable Development Goals (SDG)[3][4], with rural populations more at-risk. For example, an estimated 29% of children are stunted in Zambia’s rural Southern Province[4], which is the primary site of FishFirst! Zambia project. Such indicators suggest that chronic undernutrition and household food insecurity are significant problems in Zambia, particularly for rural populations.[5] Indeed, the Global Hunger Index categorized hunger severity in Zambia in 2019 as “serious.”[6] Food insecurity can be measured at the individual- and household-levels. For the latter, USAID developed the 9-item Household Food Insecurity Access Scale (HFIAS) to capture household food insecurity “along a continuum...from food secure to severely food insecure.”[7] which was refined into the validated Household Hunger Scale (HHS).[8][9] We adapted the HHS into the HHS II by adding 3 items related to the individual’s experience of food insecurity. We disaggregated the HHS II results by gender to compare men’s and women’s responses across the 6 individual- and household-level hunger events (HEs): HE1) In the past 4 weeks, how often did [you][other household member] miss a meal because of lack of food or resources to get food?; HE2) In the past 4 weeks, how often did [you][other household member] go to sleep at night hungry because there was not enough food?; HE3) In the past 4 weeks, how often did [you][other household member] go a whole day and night without eating anything because there was not enough food? If any HE occurred 1-2 times in the past four weeks, it is classified as ‘occasional’ food insecurity. If any HE occurred 3-10 times in the past four weeks, it is classified as ‘moderate’ food insecurity. If any HE occurred >10 times in the past four weeks, it is classified as ‘severe’ food insecurity. For HE1 and HE2, women were more likely to report occasional and moderate food insecurity at the individual level, while men were more likely to report severe food insecurity at the individual level. For HE3, women were more likely to report occasional food insecurity at the individual level, women and men were equally like to report moderate food insecurity, and men were more likely to report severe food insecurity at the individual level. For HE1 and HE2, women were more likely to report occasional and moderate food insecurity at the household level, while men were more likely to report severe food insecurity at the household level. For HE3, women were more likely to report occasional food insecurity at the household level, while men were more likely to report moderate and severe food insecurity at the household level.

Keywords— household hunger scale II, gender equity, food insecurity, low-resource small-scale fishing communities, Zambia.

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Patients Aged 65 Years or Older Prescribed Three or More Drugs with Significant Sedating or Anticholinergic Effects

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Abstract

Anticholinergic and sedating drugs are commonly prescribed in elderly populations to treat a range of conditions including hypertension and neuropathic pain. Research shows that these medications significantly increase the risk of falls in patients over the age of 65, leading to increased morbidity and mortality as well as significant cost to the NHS. The drug burden index (DBI) and Anticholinergic Cognitive Burden (ACB) score can quantify the cumulative effect of medications associated with an increased risk of falls. This should be regularly reviewed to ensure that the prescribed medications are appropriate for the individual patient. At point of data collection, North Glen Medical Practice prescribed three or more drugs with anticholinergic or sedating effects to 98 patients aged 65 or older. This audit calculated the DBI and ACB scores of a random sample of ten of these patients and considered the contribution of acute and repeat prescriptions to these values. All ten patients analysed had high DBI values (≥ 1), and 60% had an ACB score ≥ 3 (increasing their risk of adverse effects such as falls). All ten patients exhibited polypharmacy (≥ 5 medications) and 70% exhibited extreme polypharmacy (≥ 10 medications). Despite these results, only 30% of the sampled patients had undergone a medication review within the last year. The outcome of this audit was a set of recommendations: regular medication reviews should be carried out for this population of patients; safer alternatives to medications with sedating or anticholinergic effects should be considered if appropriate; care should be taken when prescribing in acute settings; and patients should be educated about the potential sedating or anticholinergic effects of over-the-counter medications and the risk this can pose.

Introduction

Over 34% of people over 65 living in Scotland fall at least once per year (Craig *et al.*, 2013). These can have serious consequences with around 10% resulting in one or more fractures and strong increases in mortality and morbidity (Gillespie *et al.*, 2012). Preventing falls and factors that contribute to falls should therefore be a high priority, particularly when this has previously been shown to cost NHS Scotland £470 million per year (Public Health Scotland, 2013). A multifactorial approach is suggested when attempting to limit falls of older adults living in community however, one of the greatest and most modifiable risks factors is polypharmacy (Winter, Watt and Peel, 2013, Hopewell *et al.*, 2018, Naseri *et al.*, 2018). This becomes particularly damaging when multiple drugs with fall-associated symptoms are prescribed. Drugs that contribute anticholinergic effects through the blocking of the neurotransmitter acetylcholine can cause

dizziness, blurred vision and confusion and can produce an accumulated effect when prescribed in conjunction with sedative drugs (Tinetti and Ginter, 1988, Ness *et al.*, 2006 and Johnell and Fastbom, 2009). Despite this, an Irish study recently found that 66% of the over 65yrs population are currently prescribed one or more of these drugs (Byrne *et al.*, 2018). One of the tools used to evaluate these adverse effects is the Drug Burden Index (DBI) which has garnered a large evidential body of support in its ability to evaluate the associated risks of polypharmacy in geriatrics (Hilmer *et al.*, 2007, Hilmer *et al.*, 2009, Wilson *et al.*, 2011 and Nishtala *et al.*, 2014). Our aim for this audit is to use the DBI to quantify drug burden within a randomised selection of patients aged over 65 at North Glen Medical Practice. We intend to investigate and highlight drug burden within these patients, quantify the risk of fall and suggest areas for prescribing improvement within the practice to better adhere to GMC guidelines.

Methodology

Data was collected using the Scottish Therapeutic Utility (STU) and electronic patient records system (EMIS) systems in North Glen Medical Practice. On the 23/09/2021 the list of 97 patients triggering the STU alert “Patients aged 65 years or older prescribed three or more drugs with significant sedating or anticholinergic effects” was retrieved and every 9th patient selected for analysis. This yielded ten patients, for whom prescribing information was extracted from STU and relevant medical information was extracted from EMIS. The data collected was anonymized and transferred to excel for analysis.

The British National Formulary (BNF) was used to classify all the prescribed drugs by their mechanism of action, and to find the minimum daily dose (MDD).

Drugs included in the calculation of the Anticholinergic Cognitive Burden (ACB) Score were identified using the list provided by the West Essex CCG. This assigns drugs a score of 0, 1, 2, or 3 depending on anticholinergic effects.

Drugs were included in calculation of the Drug Burden Index (DBI) based on relevance of side effects and, using BNF resources, drug information was systematically searched. If ‘fatigue’, ‘drowsiness’ or ‘sedation’ was highlighted, the drug was classed as sedating. DBI was also calculated for drugs with an ACB > 0. Daily dose was calculated from patients’ prescription records with individual DBI values for each

sedating or anticholinergic drug being calculated from the MDD and the patient dose (d)

as:

$$DBI = \frac{d}{d + MDD}$$

(1) The

overall DBI for each patient was calculated as the sum of the individual DBI values for each sedating or anticholinergic drug prescribed to the patient. In addition, acute and repeat medications were differentiated to allow for comparison.

The degree of polypharmacy for each patient was calculated based on the total number of items on their prescription, excluding non-drug and duplicated items. There is no official definition as to what constitutes polypharmacy, however a limit of ≥ 5 drugs has been established, with excessive polypharmacy considered to be ≥ 10 (Fulton, M. M., & Allen, E. R., 2005).

Results

Not all drugs used to calculate the DBI have an associated ACB score, as they may be sedating but not anticholinergic. However, Figure 1 shows the positive correlation found between the DBI and ACB score, demonstrating that a higher ACB score is associated with a higher overall drug burden.

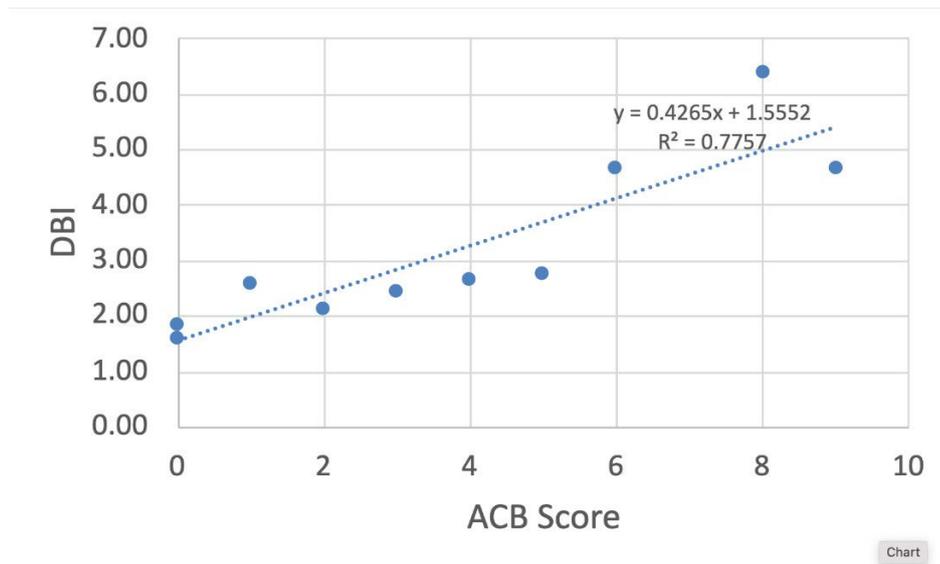


Figure 1. The relationship between drug burden index (DBI) and anticholinergic cognitive burden (ACB) score for each patient. The linear best fit equation and R2 value are shown, illustrating a positive correlation between DBI and ACB score.

Only 3 of the 10 patients included in this audit had their medications reviewed within the last year. 6 patients had not had a medication review since before the start of the COVID-19 pandemic in March 2020. One patient had not had a medication review since September 2017.

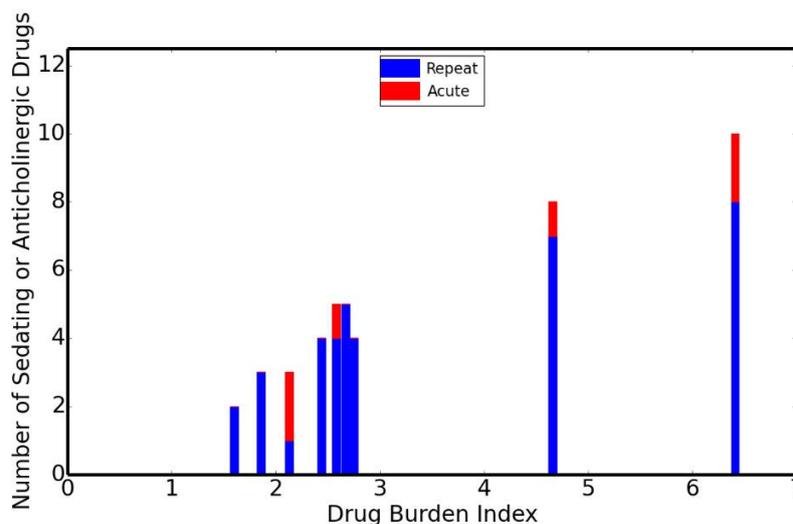


Figure 2. A bar chart illustrating the number of sedating or anticholinergic drugs each patient is prescribed as a function of their total drug burden index. Repeat prescriptions are shown in blue and acute prescriptions are shown in red.

Figure 2 illustrates the proportion of each patient's total number of anticholinergic or sedating medications prescribed through repeat and acute prescriptions. 4 of the 10 patients analysed have over one sedating or anticholinergic drugs prescribed acutely in addition to existing repeat prescriptions.

Removing the acute prescription items from the calculation of the DBI results in percentage decreases of between 23% and 63%, however this only decreased one case below the 'high' threshold (DBI = 1).

Discussion

This audit seeks to quantify the fall risk in patients aged over 65 who are prescribed three or more sedating or anticholinergic effects using their calculated DBI and ACB scores, and to investigate whether their medications have been reviewed recently. Polypharmacy is common in elderly patients, with more than 50% of over 65-year-olds in the UK prescribed more than three medications (Craig *et al.*, 2013). Previous studies have demonstrated an association between the DBI and ACB scores in the elderly population and their fall risk (Woolcot *et al.*, 2009; Chen *et al.*, 2014). It is therefore important to investigate the patterns of anticholinergic and sedating medication prescribing to elderly patients in the practice, and to provide relevant recommendations resulting from the findings.

There are currently no NICE guidelines for a recommended DBI or ACB score limit. A DBI ≥ 1 is considered 'high' and is associated with reduced physical and mental functioning and increased fall risk. An ACB score ≥ 3 is similarly considered a risk factor (Hilmer *et al.*, 2007; van der Meer *et al.*, 2019; West. Essex CCG, 2020). High ACB scores have been shown to increase risk of hospital admission due to falls and/or fractures (Hanon *et al.*, 2020).

National prescribing trends for sedating and anticholinergic drugs are not centrally recorded, making a comparison with this audit challenging. The proportion of people aged over 75 years who are dispensed more than ten strong anticholinergics (ACB Score ≥ 2) in one year in Scotland is recorded. This has remained steady at approximately 7% in Scotland since 2016. The Fife NHS Board in general prescribes below this, at between 5-7% (Public Health Scotland, 2021). These statistics are not directly comparable with the findings of this audit but may prove useful in future audits.

Patients analysed in this audit were found to have significant DBI and ACB scores. All patients had DBI ≥ 1 , meaning their drug burden was high, and 60% had a significant ACB Score ≥ 3 . This implies that these patients are at an increased risk of falls due to the sedating and anticholinergic effects of their prescribed medication. In addition, the added adverse effects of polypharmacy (Tinetti and Ginter, 1988, Ness *et al.*, 2006 and Johnell and Fastbom, 2009 and Maher *et al.*, 2013) must be considered, as all patients were prescribed more than 5 drugs in total, meaning they met the adopted definition for polypharmacy, and 70% were prescribed more than 10, meaning they meet the definition for extreme polypharmacy.

Of the ten patients, only 30% had undergone a medication review within the year prior to data collection, with 60% not reviewed since prior to the COVID-19 pandemic. The pandemic may have complicated reviewing these patients. However, medication reviews can be carried out remotely, should occur regularly to reduce cost, waste, and the adverse effects of polypharmacy, especially when the patient population are older and/or have long-term conditions (NICE Guideline No. 5, 2015).

When reviewing medications in patients with significant DBI and ACB scores it is important to consider additional drugs that may increase the risk of falls. Tetracyclic antidepressants were included in the calculation of the DBI due to their sedating effects, other classes of antidepressants such as SSRIs were not as they did not meet the criteria for a 'sedating' drug. However, antidepressants can increase the fall risk in elderly patients due to their negative influence on motor control and coordination (Chen *et al.*, 2014). A study by Yoo *et al.* (2019) found that the use of antidepressants was an important predictor of repeated falls in adults aged over 65. Over the counter (OTC) drugs with sedative effects, such as antihistamines or buscopan, can further increase the DBI and ACB score of a patient, and therefore their fall risk.

An ACB score of ≥ 4 is associated with a 20% risk of mortality in the subsequent two years compared to 7% for an ACB score of 0 (Fox *et al.*, 2011). Extrapolating from our sample of ten patients to the around one hundred patients at North Glen Medical Practice that triggered the STU alert, given that 50% of our sample had an ACB score ≥ 4 , this suggests that approximately 10 patients in this group may die in the next two years, compared to 3-4 patients if their ACB score was reduced. These excess deaths emphasise the importance of reducing the drug burden in the population of patients.

Recommendations

It is appreciated that in certain cases, prescribing high doses of multiple sedating or anticholinergic drugs may be unavoidable and it is recognised that complete removal of these prescriptions has the potential to contribute more harm.

To minimise risk of falls in elderly patients, regular medication reviews are advised. These reviews aid in monitoring patient compliance to prescription by providing an opportunity to raise any issues and modify treatment as necessary. Medication reviews are particularly important in the context of polypharmacy where multiple medications or their effects may interact or accumulate (Neutel, Perry and Maxwell, 2002).

This audit highlighted that 70% of the elderly patients in the randomised sample had not been subject to a medication review within the last year. Given the potentially adverse effects of a high DBI or ACB score in this population of patients and the subsequent risk of falls, an annual medication review is strongly advised. While the COVID-19 pandemic has made face-to-face appointments challenging, medication reviews have the potential to be offered remotely, however we appreciate the technical limitations that face the subject demographic.

40% of the patients involved in this audit were acutely prescribed sedating or anticholinergic drugs in addition to an existing burden of repeat sedating or anticholinergic prescription. Clinicians should be cautious when prescribing medications to avoid increasing side effect burden in an acute setting. While some anticholinergic or sedating medications are unavoidable alternatives to commonly prescribed medications that can be seen in Appendix 1.

The potential for patients' drug burden to increase with the addition of OTC medication should be highlighted to patients at risk of falls when prescribing. Drugs such as Buscopan or sedating antihistamines are two common examples of OTC medications patients would be unlikely to consider potentially harmful. When reviewing or prescribing medication, patients should be informed of the potential additive effects of OTC

sedating or anticholinergic medications. Information surrounding OTC medications with potential anticholinergic or sedative effect should be communicated to the patient where appropriate to avoid increasing risk of falls.

Formal training may be beneficial for clinicians surrounding the risks of polypharmacy, how to calculate patient DBI and how a scoring correlates with risk to patients (Neutel, Perry and Maxwell, 2002 and Dauphinot *et al.*, 2014). The training should help

'Recognize the potential consequences of over-diagnosis and over-treatment' as well as

'calculate safe and appropriate medication doses' as stated in the GMC guidelines for

graduates (GMC Outcomes 2 - Professional skills, 2021).

We advise this subject to be re-audited on a larger scale next year within the same demographic to better quantify the scale of drug burden at North Glen Medical Practice. We believe clinical application of DBI and ACB would be useful in quantifying risk of falling. With this in place, their effectiveness on lowering DBI and ACB would ideally be quantified in a re-audit.

Conclusions

At the time data was collected 98 patients over the age of 65 were prescribed three or more anticholinergic or sedating medications in North Glen Medical Practice. Based on a sample of ten patients, all had high DBI values with 60% having ACB scores greater than 2. 40% of the patients had increased DBI values due to acute prescribing in addition to repeat prescriptions, potentially increasing their risk of falls. Regular medication reviews are essential; however, this was carried out for only 30% of the patients analysed. To reduce the risk of falls, prescriptions should be reviewed regularly, medications swapped for safer alternatives if appropriate, care taken when

prescribing acutely and patients educated about the potential risks of OTC medications.

Contributions

Every member of the team contributed equally towards writing, reviewing, and editing of each section of this audit, ensuring a standard of quality agreed upon by the group. Candidate No. 21548 and 21540 coordinated in leading the Methods and Results. Candidate No. 21518 led the Introduction, Candidate No. 21560 led the Discussion, Candidate No. 21548 led the on both the Abstract and Conclusion, and Candidate No.

21540 led with the Recommendations.

References

Blalock, S., Renfro, C., Robinson, J., Farley, J., Busby -Whitehead, J. and Ferreri, S., (2020) 'Using the Drug Burden Index to identify older adults at highest risk for medication -related falls', *BMC Geriatrics*, 20(1).

BMJ Group and Pharmaceutical Press (2021) British National Formulary. Available at: <http://www.medicinescomplete.com> (Accessed: 23/09/2021-21/11/2021)

Craig, R., Mindell, J. and Hirani, V., (2013) 'Health survey for England', *Health and Social Care Information Centre*. (Accessed: 23/09/2021-21/11/2021)

Dauphinot, V., Faure, R., Omrani, S., Goutelle, S., Bourguignon, L., Krolak -Salmon, P., & Mouchoux, C. (2014). Exposure to anticholinergic and sedative drugs, risk of falls, and mortality: an elderly inpatient, multicenter cohort. *Journal of clinical psychopharmacology*, 34(5), 565-570. <https://doi.org/10.1097/JCP.000000000000195>

Fletcher, P., Berg, K., Dalby, D. and Hirdes, J., (2009) 'Risk Factors for Falling Among Community-Based Seniors', *Journal of Patient Safety*, 5(2), pp.61-66.

Fox, C., Richardson, K., Maidment, I.D., Savva, G.M., Matthews, F.E., Smithard, D., Coulton, S., Katona, C., Boustani, M.A. and Brayne, C. (2011), Anticholinergic Medication Use and Cognitive Impairment in the Older Population: The Medical Research Council Cognitive Function and Ageing Study. *Journal of the American Geriatrics Society*, 59: 1477-1483. <https://doi.org/10.1111/j.1532-5415.2011.03491.x>

Fulton, M. M., & Allen, E. R. (2005). 'Polypharmacy in the elderly: a literature review', *Journal of the American Academy of Nurse Practitioners*, 17(4), 123-132. doi: 10.1111/j.1041-2972.2005.0020.x

General Medical Council (2021) 'Outcomes for Graduates-Outcomes 2 Professional Skills' Available at: <https://www.gmc-uk.org/education/standards-guidance-and-curricula/standards-and-outcomes/outcomes-for-graduates/outcomes-for-graduates/outcomes-2---professional-skills#diagnosis-and-medical-management> (Accessed 1 December 2021).

Hanlon, P., Quinn, T., Gallacher, K., Myint, P., Jani, B., Nicholl, B., Lowrie, R., Soiza, R., Neal, S., Lee, D. and Mair, F., (2020) 'Assessing Risks of Polypharmacy Involving Medications with Anticholinergic Properties', *The Annals of Family Medicine*, 18(2), pp.148-155.

Maher, R., Hanlon, J. and Hajjar, E., (2013) 'Clinical consequences of polypharmacy in elderly', *Expert Opinion on Drug Safety*, 13(1), pp.57-65.

National Institute for Clinical Excellence. (2015) 'NICE Guideline No. 5, 2015', Available at: <https://www.ncbi.nlm.nih.gov/books/NBK355921/> (Accessed: 30/10/2021)

Neutel, C. I., Perry, S., & Maxwell, C. (2002). Medication use and risk of falls. *Pharmacoepidemiology and drug safety*, 11(2), 97-104. <https://doi.org/10.1002/pds.686>

Payne, R.A., Avery, A.J., Duerden, M., Saunders, C.L., Simpson, C.R., and Abel, G.A. (2014) 'Prevalence of polypharmacy in a Scottish primary care population', *Eur J Clin Pharmacol* 70, 575-581 <https://doi.org/10.1007/s00228-013-1639-9>

Public Health Scotland (2021) 'National therapeutic indicators data visualisation' Available at: <https://publichealthscotland.scot/publications/national-therapeutic-indicators-data-visualisation/national-therapeutic-indicators-data-visualisation-data-to-june-2021/dashboard-data-to-june-2021/> (Accessed: 1/11/2021)

West Essex CCG (2020) Anticholinergic side effects and Prescribing Guidance. Available at: <https://westessexccg.nhs.uk/your-health/medicines-optimisation-and-pharmacy/clinical-guidelines-and-prescribing-formularies/04-central-nervous-system/61-anticholinergic-side-effects-and-prescribing-guidance/file> (Accessed: 23/09/2021)

Woolcott, J., (2009) 'Meta-analysis of the Impact of 9 Medication Classes on Falls in Elderly Persons', *Archives of Internal Medicine*, 169(21), p.1952.

Yoo, J., Kim, C., Yim, J. and Jeon, M., (2019) 'Risk factors of repeated falls in the community dwelling old people', *Journal of Exercise Rehabilitation*, 15(2), pp.275-281.

Appendix 1

Indication	Current Drugs Suggested	Reason For Switch	
Drug			
Neuropathic Pain	Tricyclic antidepressants (Amitriptyline) Antiepileptics (Tegretol PR)	Pregabalin Gabapentin	Does not have an ACB unlike other drugs used for neuropathic pain
Pain	Opioids (Zomorph, tramadol, morphine sulfate, loperamide hydrochloride, codeine, co-codamol) Non-opioid (Nefopam hydrochloride)	N/A NSAIDs	Strong opioids are unlikely to be effectively replaced by OTC pain relief. Weaker opioids may be able to be reduced or entirely replaced using OTC pain relief NSAIDs are as potent as Nefopam in pain relief and do not cause drowsiness.
Hypertension	Ace inhibitors (Ramipril) Angiotensin II receptor agonists (Losartan potassium) Alpha adrenoreceptor blocker (Doxazosin mesilate) Ca channel blocker (Lercanidipine hydrochloride)	Candesartan Bisoprolol	Unlike ACE inhibitor, sartans could be used to treat hypertension without causing drowsiness. Bisoprolol does not cause drowsiness, however, beta blockers are not first line in treatment for hypertension

Nausea	Antipsychotics (Prochlorperazine maleate) Dopamine receptor antagonist (Metoclopramide hydrochloride)	Domperidone	Changes the prevalence of drowsiness from common/very common to uncommon.
Depression	Tetracyclic antidepressant (Mirtazapine) Serotonin and noradrenaline reuptake inhibitors (Duloxetine)	Fluoxetine Hydrochloride	Potentially has a lower ACB than other treatments for depression.
GI Spasm	Buscopan	Mebeverine	Potentially has a lower ACB.
Anxiety	Benzodiazepines (Alprazolam, clobazam, diazepam, lorazepam, midazolam, oxazepam, temazepam)	Diazepam	This benzodiazepine has the lowest ACB

An Analysis of NHS Total Disposable Food and Drink Single Item Usage: Moving Towards a Net Zero Future

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Abstract—Climate change is a major threat to global health systems' abilities to deliver high quality care. Responsible for approximately 5% of the UK's greenhouse gas emissions, the NHS has a vital role to play in climate change mitigation efforts.

In order to assess the scale of disposable food and drink items used across the NHS, Eco Medics submitted Freedom of Information (FOI) requests to 147 NHS acute trusts in England between December 2020-February 2021. These requested for the trust to specify the number of single use items used, with an associated list of costs per item and total cost of all items. Objectives were: 1. To sort and organise FOI response data, 2. to measure and analyse sorted data in terms of financial (GBP) and numerical (units) results, 3. assess the environmental impact of these single use items. In total 108 trusts responded to the FOI. Response data was varied and therefore the original scope was revised later to include only disposable cups and cutlery. Using trust responses with full available data for item unit costs, these were extrapolated to allow estimated total usage for trusts with only partial data available. Using The NHS Workforce Statistics Survey to attain an average use of each disposable item per FTE (full time equivalent) worker, we were able to extrapolate our average to NHS England as a whole.

The total estimated disposable cups and cutlery purchased and used by the NHS between 2019-2020 was both significant and alarming. This amount is estimated to emit at least 18, 136 tons of CO₂eq and cost the NHS an estimated £4 605 000. The NHS serves to preserve and improve public health, and the sustainability of its healthcare structures are key to promoting this. This study concludes the NHS should seek to reduce its reliance on single use disposable items, and, where possible a switch should be made to reusable cups.

Keywords—sustainability in health, net zero NHS, disposable food and drink items, single use items.

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Classification of Brain Tumours Using Machine Learning Models and Convolutional Neural Network

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ABSTRACT

Brain tumours are one of the most dangerous diseases of their kind. For increasing the survival rates for patients, early identification of the tumour is considered pivotal for identifying its spread, as well as for administering appropriate treatment. This study focuses on classifying the magnetic resonance imaging (MRI) images of brain tumours, which have two main tasks: binary and multi-classifications. In binary classification, the aim is to classify the images into images, both with and without tumours; for the tasks, three machine learning models are used: support vector machine (SVM), random forest (RF), and decision tree (DT). Furthermore, the convolutional neural network (CNN) model is used for both types of binary and multi-classifications. In the multi-classifications, the model classifying the MRI is imaged into four classes: images without tumours and images with three kinds of tumours: glioma, meningioma, and pituitary tumours. This studying preprocessing technique is applied to the MRI images to increase performance. Moreover, in the multi-classifications, task data augmentation is used to increase the accuracy of the CNN model. The binary brain tumour classification result shows a test accuracy of 95%, 96%, 93%, and 81% in the CNN, RF, DT, and SVM—respectively. Meanwhile, the CNN used in multi-classification has a test accuracy of 94%.^{1,2,3}

Index Terms— Brain Tumor Image Classification, Deep Learning, Convolutional Neural Network, Random Forest, Decision Tree, Support Vector Machine, Hyper-Parameter Optimization

1. INTRODUCTION

Brain tumours are a frequent malignancy, with roughly 24,000 people being diagnosed with the disease each year.

¹The link of Github: [link-to-your-github-project](#)

²The link of Google Drive: [link-to-your-Google-Drive-project](#)

³Note some files not uploaded in Github, you can find all the files in Google Drive

These tumours are very aggressive and have poor health-care numbers, as seen by a five-year survival rate of 33.2% [1]. Generally, there are two main types of brain tumours: benign and malignant tumours. A malignant tumour is identified when it begins to spread to other parts of the brain, as well as to places outside the brain. In contrast, a benign tumour does not spread to other parts of the brain. This research focuses on three brain tumour forms: glioma, meningioma, and pituitary. Glioma tumours target the brain and spinal cord, a meningioma tumour is a tumour that grows on the lining of the brain and spinal cord, and the pituitary tumour is a tumour that grows on the pituitary gland [1]. Early diagnosis and identification of brain tumour types are both essential for effective treatment; this, in turn, helps determine the condition of patients and increase their survival rates. Magnetic resonance imaging (MRI) technology uses magnetic fields to capture images of organ anatomy, which are then recorded onto a computer; this is a widely-accepted method for providing such images. This MRI method produces images that are used to classify the state of brain tumours. However, the process that radiologists go through for assessing the results of MRI pictures results in a rather long delay in performing necessary surgery [2].

This study focuses on classifying the MRI images of brain tumours using both machine learning and deep learning. Machine learning makes the computer system learn and adapt without explicitly being programmed. Deep learning is a branch of machine learning that is based on developing a system to study multiple level representation by creating hierarchical features; where the higher level is determined from, and both the lower- and similar lower-level features can help identify numerous higher-level features [3]. This research has two main tasks. Task A is for classifying the MRI images into images with and without tumours. Task B is for classifying the MRI images into four classes: images without tumours and images with three kinds of tumours: glioma, meningioma, and pituitary tumours. Machine learning algorithms are used to solve task A, while deep learning—especially

the convolutional neural network (CNN)—is used to solve both tasks. This paper is divided into six sections and are as follows. Section 2 is a literature survey that provides an overview of potential approaches to solving these tasks. Section 3 is the description of each model that is used in this paper. Section 4 provides the details of the implementation of both tasks. Section 5 shows the results of the algorithm. Finally, section 6 contains the conclusion and highlights the main result of this paper.

2. LITERATURE SURVEY

The detection and classification of brain tumours using machine learning has been an area of interest for many researchers in recent years. The main reason is the need for early diagnosis of brain tumours in order to assist patients in getting the initial treatment that they need to increase their chances of survival. The brain consists of billions of cells and is the most complicated vital organ. It is required to implement an accurate technique that can define the layout of the brain and detect the tumours using MRI images[3, 4, 5, 6].

Many researchers have conducted significant work classifying brain tumours using non-deep machine learning methods. The largest benefit of using a classical machine learning method is that it is understandable and requires less computational cost and recourse. Support vector machine (SVM) is the most famous and influential algorithm for classifying and detecting brain tumours in classical machine learning[2]. Some authors used SVM and expanded their research to discuss the available preprocessing methods of the MRI image in the classification of brain tumours; including increased image brightness, threshold value, R-filtering skull, masking, and feature extraction[7]. Other scientists used different classification methods, such as randomized forest (extra-trees), for introducing a new segmentation method used by appearance and context-based features [8]. Moreover, other methods that have been used in detecting and classifying tumours are instance-based K nearest using log and Gaussian weight kernels [9, 10] and sequential minimal optimization (SMO)[11].

However, there are drawbacks to traditional machine learning techniques, which are due to the need for previous knowledge about the domain. The task of manual features extraction is both tedious and very time-consuming. Furthermore, some of the earlier studies have indicated that it is essential to segment the region-based tumour before applying feature extraction. Moreover, before using the classification model, feature selection is necessary to minimize the number of features; generally, there is no single united feature extraction method that is applicable [12]. On the other hand, deep learning is a subset of machine learning that allows computers to learn from experience and comprehend the world in the terminology of hierarch concepts. Research in the classifications of brain tumours using deep learning is an interest of many scientific studies. One study finds a state-of-the-art result

that compares with other past methods in 2019; researchers proposed a deep learning method using residual network (ResNet), which is a type of deep learning architecture for the designed model. Data augmentation techniques are used to increase the accuracy and their result showed 99% for the image-level and 97% accuracy for the patient-level[12]. Other researchers put an effort into conducting and exploring extensive literature on state-of-the-art in brain tumours classification from 2015 to 2020[13]. In 2021, research proposed a new model—namely—the mask region-based convolution neural network (Mask RCNN). This model achieved 98.34% accuracy by using the bounding process and segmentation to detect the exact tumour location[14]. Other studies focused on improving the performance of the CNN model by tuning its hyper-parameters and such hyper-parameters, number of convolutional layers, filter size, and activation functions[1, 15].

3. DESCRIPTION OF MODELS

This section presents the specific description of all models that are used to classify brain tumours. The machine learning models for binary classification of the brain tumours are elaborated on in task A. Task B illustrates the deep learning model description that is used for both binary and multi-class classifications.

3.1. Machine Learning for Binary Classification

In this task, the models must classify the preprocessing MRI images into two classes: images without tumours and images with tumours. The first model used to solve this classification problem is SVM. Many researchers recommend using this model for brain images classification, as they find it to be an effective model in classical machine learning [2, 7, 16]. However, to make comprehensive results, other models—such as random forest and decision tree—are used to find the best model. A brief description of all models used for this task are as follows:

3.1.1. Support Vector Machine (SVM)

SVM is a linear model that may be used to address classification and regression problems. SVM can solve both linear and nonlinear problems. The concept of this model is transferring data space to a higher dimension on another space using a kernel function. The hyperplane function that is used for splitting the data is as follows:

$$f(x_i) = \sum_{n=1}^N \alpha_n y_n K(x_n, x_i) + b$$

Where $K(x_n, x_i)$ is the kernel function, x_n is the support vector data, α_n is the Lagrange multiplier, and y_n is the labels class of the data set. There are four kernel types commonly

used: SVM, linear kernel, sigmoid kernel, and RBF kernel. Moreover, there are two hyper-parameters in SVM that affect the accuracy of the model: γ and C . γ , in the hyper-parameter, is used to identify the amount of curvature needed in decision boundary. C , the other hyper-parameter, is used for the soft-margin cost function that controls the influence of the vectors. A research paper used the three types of kernel functions; linear, sigmoid, and RBF; to classify the brain tumour. Their results showed that the model with RBF had the highest accuracy among the others [16]. For that reason, the RBF kernel used in this model has the same range of hyper-parameters.

3.1.2. Random Forest (RF)

It is a bagging approach that is based on a classification and regression tree (CART). It divides the data into multiple homogeneous subsets known as regression trees (n -tree) by using recursive partitioning and then averages the results of all trees. Each tree is developed to its maximum size independently based on a bootstrap sampling from the training data set, all without pausing the selection of the input variables at each node. RF exploits randomness in the classification process by choosing a random subset of variables (m -try) to split each node's criteria and tree [17]. In this model, the two parameters (m -try and n -tree) are optimized during the training method. The values of n -tree and m -try are evaluated in the range of 10 to 30. After training the model with high-quality parameters, the superior RF-based model that was adopted is the one that achieved high classification performance.

3.1.3. Decision Tree (DT)

The technique of learning decision trees from class-labelled training tuples is known as decision tree DT induction. A decision tree DT is a type of tree structure that resembles a flowchart. The DT algorithm's structure is comprised of numerous nodes; including a root, a decision, and a leaf. The root node commences the tree, whereas the decision nodes are in charge of making decisions (i.e., moving from one node to another). The leaf nodes are yields from the decision nodes. Some DT algorithms can only create binary trees (with two internal nodes), while others can build nonbinary trees [18]. There are two factors taken into consideration during training. The maximum number of features (f -max) to include in the search for the ideal split and the maximum depth (d -max) of the tree, expanding nodes until all leaves are pure. This model's parameters vary from 10 to 30. In addition, parameter optimization has been performed during the training and the top-level model is generated using the best parameters. Classification rules can be simply converted from DTs. DT classifiers are appropriate for exploratory knowledge discovery, in which it does not require domain expertise or parameter setting. DTs are beneficial when dealing with high-dimensional data.

3.2. Deep Learning for Binary and Multi-Classification

3.2.1. Convolutional Neural Network (CNN)

CNN is a deep neural network type that is highly recommended to recognize images and videos. CNN has mostly been used in image processing because of its ability to distinguish patterns in pictures [12]. Furthermore, other studies have decided to use deep learning models—especially CNN—for brain tumour classification. For that reason, this paper investigates using such a model for binary classification and multi-classification tasks [14][12]. Also, this model chooses as a primary implementation for the multi-class classification of the brain tumour to classify the images into four classes. CNN architecture consists of three layers: convolutional, pooling, and fully connected. These layers are piled on top of each other to produce CNN. The convolution layer extracts picture features that provide us a network with a visual grasp of the data set. In addition, this layer is concerned with the usage of learnable kernels. The convolutional layer typically convolves each filter across the spatial dimensions of the input to generate a feature map as its output. The pooling layer, used to reduce the dimensionality of the convolved feature, minimizes the number of parameters and the complexity of the model. The fully connected layer purpose establishes network linearity, which consists of multiple neurons directly linked to other neurons in the two adjacent layers but not to any layers inside them. In CNN, the weights of the neural network are updated and learn the optimizer function. The optimizer function uses the misclassifying error or loss to readjust the filters and weights of the network [12].

4. IMPLEMENTATION

This paper uses an image-based data set that consists of 3,000 MRI scans of the human brain. The shape of the image in pixels is 512 Height and 512 widths. The data is divided into training and validation sets using the train test split from scikit-learn library. The training data is 80% (2,400 images) and are used for classification model training. In contrast, the remaining 20% (600 images) are utilized to evaluate the model's performance. Moreover, others' testing data (200 images) will be used to test the models' performance and check if the models are either overfitting or underfitting [19]. All the codes of the machine learning are implemented using the Jupyter notebook in Anaconda software with Python 3.3.11. For deep learning, the code is implemented by using Google Colab for consuming the time. A preprocessing procedure is used to increase the MRI images' quality of brain tumours for this data. It also aids in improving the parameters of MRI images; the median filter, edge detection, thresholding technique, watershed segmentation, and morphological operation. First, the primary aim of a filter is to reduce noise. However, it is sometimes used to highlight or ignore specific characteristics of an image. The median filter is beneficial

for some forms of random noise because it has strong noise suppression capabilities with considerably less blurring than linear smoothing filters of the same size. Second, edge detection is a fundamental problem in image processing, especially in the domains of feature identification and feature extraction, which are concerned with finding discontinuities in a picture [20]. Third, the skull can be removed using intensity thresholding; this is then followed by a morphological procedure to provide the requisite brain area for tumour detection. A thresholding strategy is used to remove any minor white noises in the image using the morphological opening. Fourth, the watershed segmentation method is utilized to identify places where we were unsure on whether they were foreground or background. Last, the morphological operation shows only the region of the image with the highest intensity that contains the tumour, which is the section of the image that forms our intended extraction.

4.1. Task A: Binary Classification

4.1.1. Machine Learning

In this research, some traditional machine learning algorithms (such as SVM, RF, and DT) are suggested to improve tumour monitoring in brain images. The suggested structure incorporates the following consecutive steps, as shown in Fig.1: (a) RGB image preprocessing; (b) using morphological features as inputs to the models, divide the data set, and train different models; (c) examine the performance of the model; (d) to improve performance, adjust the hyper-parameters in all models, and save the superior model; and (f) to test the model's robustness by using new samples. One of the focuses of this study is to examine various classification models to select the best one. The data set is used as an input for these models. We fine tune the model by focusing on the essential hyper-parameters for each model. For the SVM model, the gamma and C values are set to [0.00001, 0.0001, 0.001, 0.01] and [0.1, 1, 10, 100, 1000, 10000]—respectively. Next, a selection of the best combination of these values are chosen to get the highest accuracy result. The same is done for the RF and hyper-parameters m-try and m-trees, which are set from 10 to 30. Moreover, for f-max and d-max—which are the hyper-parameters of the DT model—they are set from 10 to 30. Generally, the image data are randomly fed to the model in the first loop. The low-level parameters are dropped during each loop and the superb parameters are kept with respect to the highest contribution. Then, each model outcome is compared to decide on high-quality parameters with a minimal model loss for accurate brain tumour monitoring. Table 1 represents the optimum hyper-parameters.

4.1.2. Convolutional Neural Network

CNN is a powerful image classification tool with high accuracy in addressing and classifying images. It has many hyper-

Table 1. Optimum hyper- parameter

Models	Hyper-Parameters	Result
SVM	C= 100	gamma= 0.0001
RF	Max Depth = 19	Max Features= 23
DT	Max Depth = 17	Max Features= 15

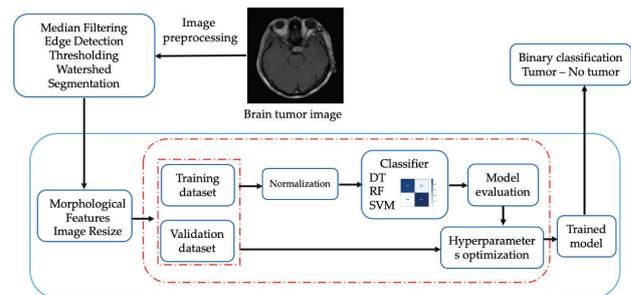


Fig. 1. The methodology Of binary Classification

parameters that can affect the model's performance. A study investigated the tuning of the hyper-parameters of CNN by using a search grid optimizer. The authors proposed three different models for classifying the brain tumour images. One of the models is the binary classification model using CNN that has an accuracy of 99%. For that reason, in this task, the selection of hyper-parameters and the model design of the CNN are according to their optimum results [15]; where Table 2 represents these hyper-parameters and Table 3 represents the model design. This model uses the Keras and TensorFlow library, a powerful tool and free open source in Python for developing and evaluating deep learning models. Table 3 describes the model architecture, where the model inputs are the preprocessing images after re-scaling and resizing to 277 x 277 pixels. The model proposed two convolutional layers, two pooling layers, a dropout layer, and two dense layers. The two convolutional layers with filters size 6, the first layer has 128 channels used for learning a feature's purpose (such features as colours, and edges). After this layer, there is a normalization layer that helps to standardize the input into mini batch. The second convolutional layer, with 96 channels, focuses on learning deeply for more complex features. After each layer, there are pooling layers and activation functions of type "ReLU." Moreover, one dropout layer helps to reduce the overfitting by regularising the neural networks to improve the model performance. Two fully-connected layers are given input to the sigmoid function to make the final classification output. This model uses the Adam optimizer function with a default learning rate for optimization. As represented in Table 2, number of epochs in this model is 100, which may result in overfitting in the model. The built-in callback in the Keras module uses early stopping to avoid this problem; this

happens by monitoring the validation loss as performance every 15 epochs during the training. It will look for minimum change that is defined as 'min delta,' which means that change less than this value will count as no improvement. Furthermore, another hyper-parameter is called mode; in this model, it is defined by 'max,' which means that the mode will stop when the quantity monitored stop increases. The graphs in Fig2 represents the performance of this model.

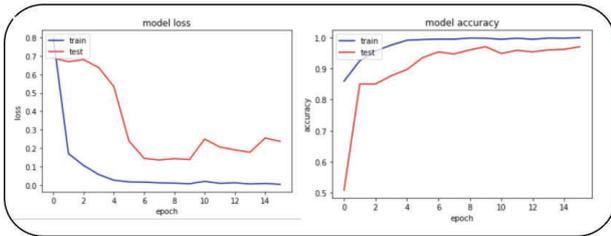


Fig. 2. Performance of the CNN model Task A

Table 2. Hyper-parameters Values for CNN Models

Hyper-parameter	Task 1	Task 2
batch_size	32	32
epochs	100	100
min_delta	0.001	-
patience	15	-
mode	'max'	-
monitor	'val_loss'	-
droupout value	0.3	0.2 , 0.5

Table 3. CNN Model Design for Binary Classification

Layer	Filter	Kernel_size	Activation
Input (277,277)			
Conv2D	128	6.6	Relu
BatchNormalization			
Maxpooling2D			
Conv2D	96	6.6	Relu
Maxpooling2D			
Flatten			
Dense	512	-	Relu
Dropout			
Dense	1	-	sigmoid

4.2. Task B: Multi-Classification

This task is aimed at classifying the MRI images into four classes, namely images without tumours and images with three kinds of tumours (i.e., glioma tumours, meningioma

tumours, and pituitary tumours). In addition to the previously described preprocessing, data augmentation is used in this task to increase the amount of data by changing the images' characteristics using the image data generator library form Keras. There are four techniques of augmentation in this task. First, the rotation that randomly rotates the images by 30 degrees clockwise. Second, zooming in on the images either adds new pixel values or interpolates the respective pixel values. Third, shifting by randomly moving the pixels in one direction without changing the image dimensions. Last, flipping the images could be horizontal and vertical, just use the horizontal flip in this task[1]. This task solves using CNN; the model architecture implemented, according to a previous study, focuses on classifying brain tumours into four classes. Their aim was for tuning the CNN's hyper-parameters in different scenarios to achieve optimal results [1]. Table 4 illustrates the model's design, consisting of five convolutional layers with different channels. After each convolutional layer, there are the pooling and dropout layers. The value of the dropout layers is 0.2, except for the last one (which is equal to 0.5). The pooling layers assist in preventing over-fitting and improving the model's performance. Relu is the main activation function used in this task, expect the last one; softmax is used to identify the final class of the images. However, the main difference between my code and the reference code is that I used Adam optimizer without identifying the learning rate. Furthermore, the number of epochs are equal to 100, with 32 batch size and Fig ref3 representing the accuracy and the loss of the model during the training.

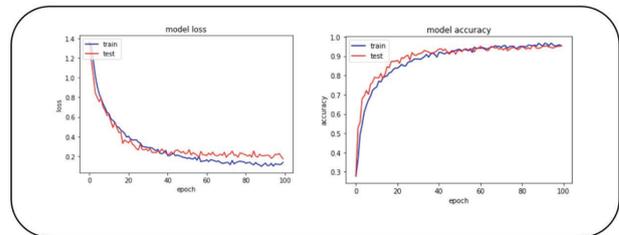


Fig. 3. Performance of the CNN model Task B

5. EXPERIMENTAL RESULTS AND ANALYSIS

The proposed modules performance is quantitatively examined using a variety of metrics; including precision (Pr), overall accuracy (Acc), F-measure (Fm), and recall (Re)—as shown in the following equations:

$$Acc = \frac{\sum TP + \sum TN}{\sum TP + \sum TN + \sum FP + \sum FN}$$

$$Pr = \frac{\sum TP}{\sum TP + \sum TF}$$

Table 4. CNN Model Design for Binary Classification

Layer	Filter	Kernel_size	Activation
Input (128,128)			
Conv2D	64	5.5	Relu
Maxpooling2D			
Dropout			
Conv2D	128	3.3	Relu
Maxpooling2D			
Dropout			
Conv2D	128	3.3	Relu
Maxpooling2D			
Dropout			
Conv2D	128	3.3	Relu
Maxpooling2D			
Dropout			
Conv2D	265	3.3	Relu
Maxpooling2D			
Dropout			
Flatten			
Dense	512	-	Relu
Dropout			
Dense	4	-	Softmax

$$Re = \frac{\sum TP}{\sum TP + \sum FN}$$

$$Fm = 2 \times \left(\frac{Precision \times Recall}{Precision + Recall} \right)$$

The Table 5 represents the results of the validation accuracy of the models that are used in this paper. Generally, the result of the binary classification task has a close validation accuracy, ranging from 95% to 97%. Meanwhile, both the CNN and RF model accuracies have the highest accuracy among the other models—equaling to 97%. The DT and SVM models have a validation accuracy of 96% and 94%, respectively. From each model’s confusion matrix, the SVM has 34 labels from 600 that are misclassified from the validation set. In contrast, the RF models incorrectly classify 17 labels—half the number of SVM. Moreover, compared with machine learning and deep learning in this task, we could see that the good tuning for the values of the hyper-parameters in the machine learning and deep learning could improve the performance of the models. The RF and CNN almost have the same accuracy and correctly classify the same number of labels. For Task B, the CNN model that is used for classifying the images into four classes achieved a 95% validation accuracy. As illustrated in the confusion matrix in Fig4 of this task, the model can accurately classify the pituitary tumour, meningioma tumour, and no tumour classes; the number of images missed classifying in these classes are two, six, and eight—respectively. However, the most incorrect classification label belongs to the glioma tumour class; in which

the model misaddressed 12 images. Generally, the number of misaddressing in this task equals 28 images for 600 images.

Testing data are used to check on the performance of the models to see if it is overfitting or underfitting. These data consist of 200 MRI images that were not used in the training and validation process. Table6 shows the result of testing these data on the module. It illustrates that all the models receive a comparable accuracy to the validation set. This means that there is no overfitting or underfitting in the models. However, the SVM model is an exception, having 81% accuracy on the test data and less than 13% of the validation accuracy. This means that the performance of the model has overfitting.

Table 5. Validation Accuracy

	Precision	Recall	F1
Task A:SVM	94%	94%	94%
Task A:RF	97%	97%	97%
Task A:DT	96%	96%	96%
Task A:CNN	97%	97%	97%
Task B:CNN	95%	95%	95%

Table 6. Test Accuracy

SVM	RF	DT	TaskA:CNN	TaskB:CNN
81%	96%	93%	95%	94%

Confusion Matrix, without Normalization

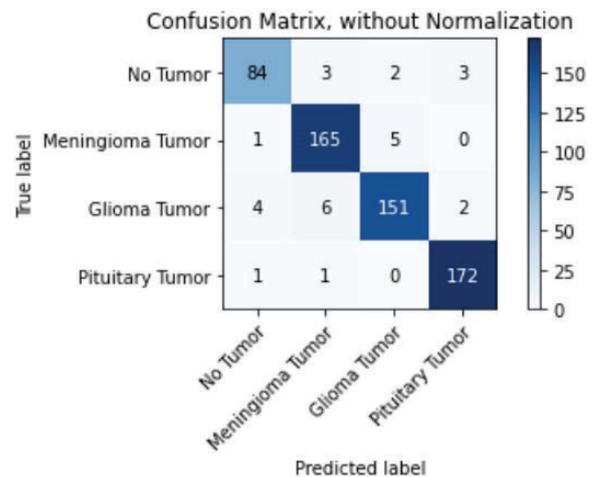


Fig. 4. Confusion Matrix of CNN in Task B

6. CONCLUSION

Early detection and classification of brain tumours have been considered key in assisting appropriate medical treatment.

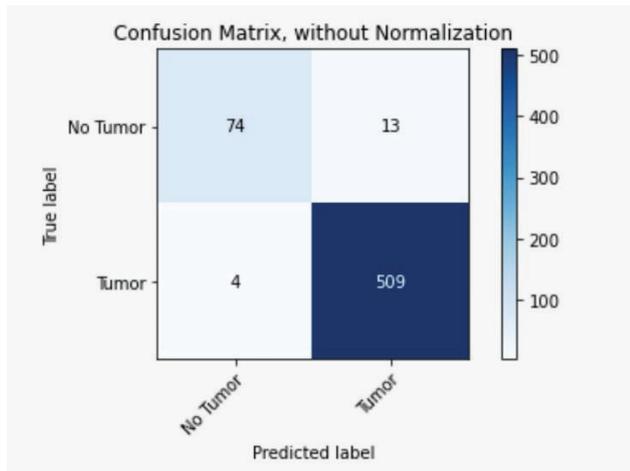


Fig. 5. Confusion Matrix of RF

This study investigated and classified brain tumours into two main tasks: binary classification and multi-class classifications. In binary classification, machine learning and deep learning models were used (SVM, RF, DT, and CNN) to classify the data into images with tumours and images without tumours. Out of these models, the best results obtained in RF and CNN was 96% and 95%, respectively. In multi-classification, the data were classified into four classes: no tumour, glioma, meningioma, and pituitary. This task was solved using the CNN model with five convolutional layers and the accuracy of the test data was 94%. In the future, it is encouraged to discover novel methods for brain tumour classification and to navigate new parameters for the potential model.

7. REFERENCES

- [1] Agus Eko Minarno, Mochammad Hazmi Cokro Mandiri, Yuda Munarko, and Hariyady Hariyady, "Convolutional Neural Network with Hyperparameter Tuning for Brain Tumor Classification," *Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control*, 2021.
- [2] Mahmoud Abd-Ellah, Ali Ismail Awad, Ashraf A. M. Khalaf, and Hesham Hamed, "A review on brain tumor diagnosis from mri images: Practical implications, key achievements, and lessons learned," *Magnetic Resonance Imaging*, 06 2019.
- [3] Mircea Gurbina, M. Lascu, and Dana-Nicoleta Lascu, "Tumor detection and classification of mri brain image using different wavelet transforms and support vector machines," *2019 42nd International Conference on Telecommunications and Signal Processing (TSP)*, pp. 505–508, 2019.
- [4] Himar Fabelo, Samuel Ortega, Adam Szolna, Diederik Bulters, Juan Pineiro, Silvester Kabwama, Aruma J-O'Shanahan, Harry Bulstrode, Sara Bisshopp, Bangalore Kiran, Daniele Ravi, Raquel Lazcano, Daniel Madroñal, Coralia Sosa, Carlos Espino, Mariano Marquez, Maria Plaza, Rafael Camacho, David Carrera, and Roberto Sarmiento, "In-vivo hyperspectral human brain image database for brain cancer detection," *IEEE Access*, vol. PP, pp. 1–1, 03 2019.
- [5] TK Keerthana and Sobha Xavier, "An intelligent system for early assessment and classification of brain tumor," in *2018 Second International Conference on Inventive Communication and Computational Technologies (ICICTCT)*. IEEE, 2018, pp. 1265–1268.
- [6] S Suja, Nimmy George, and Annie George, "Classification of grades of astrocytoma images from mri using deep neural network," in *2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI)*, 2018, pp. 1257–1262.
- [7] Golda Tomasila and Andi Wahyu Rahardjo Emanuel, "Mri image processing method on brain tumors: A review," *AIP Conference Proceedings*, vol. 2296, no. 1, pp. 020023, 2020.
- [8] Adriano Pinto, Sérgio Pereira, Higinio Correia, Jorge Oliveira, Deolinda M. L. D. Rasteiro, and Carlos Alberto Silva, "Brain tumour segmentation based on extremely randomized forest with high-level features," *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pp. 3037–3040, 2015.

Confusion Matrix, without Normalization

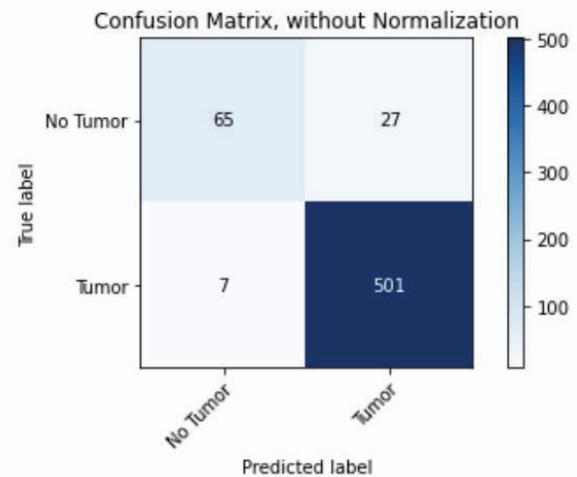


Fig. 6. Confusion Matrix of SVM

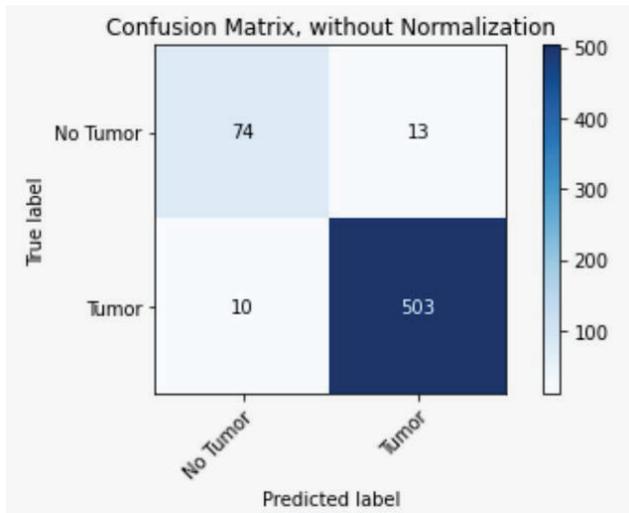


Fig. 7. Confusion Matrix of DT

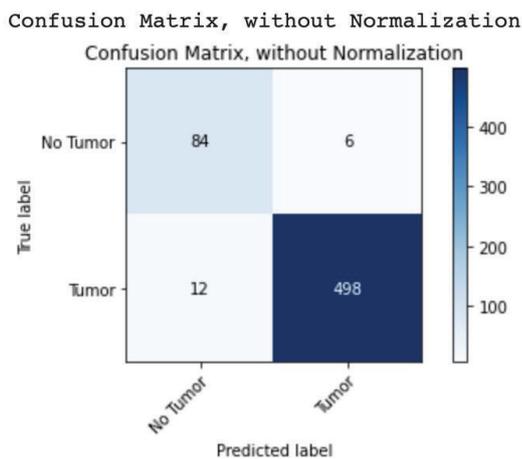


Fig. 8. Confusion Matrix of CNN in Task A

- [9] Saumya Chauhan, Aayushi More, Ritumbhara Uikey, Pooja Malviya, and Asmita Moghe, “Brain tumor detection and classification in mri images using image and data mining,” in *2017 International Conference on Recent Innovations in Signal processing and Embedded Systems (RISE)*, 2017, pp. 223–231.
- [10] G. Kharmega Sundararaj and V. Balamurugan, “Robust classification of primary brain tumor in computer tomography images using k-nn and linear svm,” in *2014 International Conference on Contemporary Computing and Informatics (IC3I)*, 2014, pp. 1315–1319.
- [11] S. N. Deepa and B. Aruna Devi, “Neural networks and smo based classification for brain tumor,” *2011 World Congress on Information and Communication Technologies*, pp. 1032–1037, 2011.
- [12] Sarah Ismael, Ammar Mohammed, and Hesham Hefny, “An enhanced deep learning approach for brain cancer mri images classification using residual networks,” *Artificial Intelligence in Medicine*, vol. 102, pp. 101779, 12 2019.
- [13] Maria Nazir, Sadia Shakil, and Khurram Khurshid, “Role of deep learning in brain tumor detection and classification (2015 to 2020): A review,” *Computerized Medical Imaging and Graphics*, vol. 91, pp. 101940, 05 2021.
- [14] Momina Masood, Tahira Nazir, Marriam Nawaz, Awais Mehmood, Junaid Rashid, Hyuk-Yoon Kwon, Toqeer Mahmood, and Amir Hussain, “A novel deep learning method for recognition and classification of brain tumors from mri images,” *Diagnostics*, vol. 11, pp. 1–19, 04 2021.
- [15] Emrah Irmak, “Multi-Classification of Brain Tumor MRI Images Using Deep Convolutional Neural Network with Fully Optimized Framework,” *Iranian Journal of Science and Technology - Transactions of Electrical Engineering*, vol. 45, no. 3, 2021.
- [16] Jaeyong Kang, Zahid Ullah, and Jeonghwan Gwak, “Mri-based brain tumor classification using ensemble of deep features and machine learning classifiers,” *Sensors*, vol. 21, no. 6, pp. 2222, 2021.
- [17] Leo Breiman, “Random forests,” *Machine Learning*, vol. 45, no. 1, pp. 5–32, 2001.
- [18] Jiawei Han, Jian Pei, and Micheline Kamber, *Data mining: concepts and techniques*, Elsevier, 2011.
- [19] Sartaj Bhuvaji, Ankita Kadam, Prajakta Bhumkar, Sameer Dedge, , and Swati Kanchan, “Brain Tumor Classification (MRI), Kaggle,” 2020.
- [20] Luis Cadena, Nikolai Espinosa, Franklin Cadena, Anna Korneevea, Alexey Kruglyakov, Alexander Legalov, Alexey Romanenko, and Alexander Zotin, “Brain’s tumor image processing using shearlet transform,” in *Applications of Digital Image Processing XL*, Andrew G. Tescher, Ed. International Society for Optics and Photonics, 2017, vol. 10396, pp. 255 – 260, SPIE.

Expression of PGC-1 Alpha Isoforms in Response to Eccentric and Concentric Resistance Training in Healthy Subjects

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Abstract

Background and Aim: PGC-1 alpha is a transcription factor that was first detected in brown adipose tissue. Since its discovery, PGC-1 alpha has been known to facilitate beneficial adaptations such as mitochondrial biogenesis and increased angiogenesis in skeletal muscle following aerobic exercise. Therefore, the purpose of this study was to investigate the expression of PGC-1 alpha isoforms in response to eccentric and concentric resistance training in healthy subjects.

Materials and Methods: Ten healthy men were randomly divided into two groups (5 patients in eccentric group - 5 in concentric group). Isokinetic contraction protocols included eccentric and concentric knee extension with maximum power and angular velocity of 60 degrees per second. The torques assigned to each subject were considered to match the workload in both protocols, with a rotational speed of 60 degrees per second. Contractions consisted of a maximum of 12 sets of 10 repetitions for the right leg, a rest time of 30 seconds between each set. At the beginning and end of the study, biopsy of the lateral broad muscle tissue was performed. Biopsies were performed in both distal and proximal directions of the lateral flank. To evaluate the expression of PGC1 α -1 and PGC1 α -4 genes, tissue analysis was performed in each group using Real Time PCR technique. Data were analyzed using dependent t-test and covariance test. SPSS21 software and Exell 2013 software were used for data analysis.

Results: The results showed that intra-group changes of PGC1 α -1 after one session of activity were not significant in eccentric ($p = 0.168$) and concentric ($p = 0.959$) groups. Also, inter-group changes showed no difference between the two groups ($p = 0.681$). Also, intra-group changes of PGC1 α -4 after one session of activity were significant in eccentric group ($p = 0.012$) and concentric group ($p = 0.02$). Also, inter-group changes showed no difference between the two groups ($p = 0.362$).

Conclusion: It seems that lack of significant changes in the desired variables due to the lack of exercise pressure is sufficient to stimulate the increase of PGC1 α -1 and PGC1 α -4. And with regard to reviewing the answer, it seems that the compatibility debate has different results that need to be addressed.

Keywords: Eccentric contraction, Concentric contraction, PGC1 α -1 , PGC1 α -4

1. Puigserver P, Wu Z, Park CW, Graves R, Wright M, Spiegelman BM. A cold-inducible coactivator of nuclear receptors linked to adaptive thermogenesis. *Cell*. 1998;92(6):829-39.
2. Puigserver P, Spiegelman BM. Peroxisome proliferator-activated receptor- γ coactivator 1 α (PGC-1 α): transcriptional coactivator and metabolic regulator. *Endocrine reviews*. 2003;24(1):78-90.
3. Olesen J, Kiilerich K, Pilegaard H. PGC-1 α -mediated adaptations in skeletal muscle. *Pflugers Archiv : European journal of physiology*. 2010;460(1):153-62.
4. Ruas JL, White JP, Rao RR, Kleiner S, Brannan KT, Harrison BC, et al. A PGC-1 α isoform induced by