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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 Science**

**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.

**Open Science**

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. Theses 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:

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

- o  are often not applicable at the individual level
- o  do not take into account the broader social and economic function of scientific research
- o  are not adapted to the increased scale of research
- o  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:

- o combining the power of ideas and knowledge from different actors to co-create new products and find solutions to societal needs
- o creating shared economic and social value, including a citizen and user-centric approach
- o 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.

**Open Science**

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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All submitted manuscripts are subject to the scholarly research review process, in which there are three stages of evaluation for consideration: pre-review manuscripts, chair-review presentation, and final-review manuscripts. All submitted full text papers, that may still be withstand the editorial review process, are presented in the conference proceedings. Manuscripts are tracked and all actions are logged by internal and external reviewers according to publication policy. External reviewers' editorial analysis consists of the evaluation reports of the conference session chairs and participants in addition to online internal and external reviewers' reports. Based on completion of the scholarly research review process, those manuscripts meeting the publication standards are published 10 days after the event date.

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# Smart Technology for Hygrothermal Performance of Low Carbon Material Using an Artificial Neural Network Model

Manal Bouasria, Mohammed-Hichem Benzaama, Valérie Pralong, Yassine El Mendili

***Abstract***— Reducing the quantity of cement in cementitious composites can help to reduce the environmental effect of construction materials. By-products such as ferronickel slags (FNS), fly ash (FA) and waste as *Crepidula fornicata* shells (CR) are promising options for cement replacement. In this work, we investigated the relevance of substituting cement with FNS-CR and FA-CR on the mechanical properties of mortar and on the thermal properties of concrete. Foraging intervals ranging from 2 days to 28 days, the mechanical properties are obtained by 3-point bending and compression tests. The chosen mix is used to construct a prototype in order to study the material's hygrothermal performance. The data collected by the sensors placed on the prototype were utilized to build an artificial neural network.

***Keywords***— Artificial neural network, cement, circular economy, concrete, by products

## I. INTRODUCTION

THE production of cement is increasing widely around the world due to the expansion of the construction sector and it produces a significant amount of $CO_2$. Multiple options for cementing systems have been stated. The partial replacement of cement by supplementary cementing materials presents a promising solution [1]. Cement can be partially replaced by different supplementary cementitious materials (SCM) such as blast furnace slag [2], fly ash [3], [4] and silica fume [3], [5], [6] and thus results in the valorization of industrial by-products and the conservation of natural resources [7]. The enhanced use of SCM will lead to the reduction of $CO_2$ footprint. One of these products is fly ash, which is produced at large quantity [8]. Only a limited percentage is reused, the rest is treated as waste and is dumped and stored on the surface. This brings serious risks of air pollution and water contamination by leaching [3], [9], [10] due to their content of potentially toxic elements. Among these elements, we find Cu, Zn, As, Pb, Cd, Ni, B and Hg which constitute a serious threat to human health and to our ecosystems.

The heat and moisture transfers in porous building materials and envelopes is a complex phenomenon, and its relative impact is proven to be influenced by many factors including the climatic conditions and the hygroscopic properties of the material. Several models were used to simulate the hygrothermal behavior of concrete using a physical model with Wufi tools [5], [11] or black box models with ANN models [12]–[14]. We found only three works on the use of ANN models for the hygrothermal simulation at the wall scale [12]–[14]. For this reason, our interest is focused on data-driven model to simulate the heat and moisture transfer of an experimental cell. Indeed, data-driven approaches are well recognized for their outstanding performances to describe the behavior of a system. The simulation of the hygrothermal performance by ANN models will be executed without any physical knowledge, in contrast to what is implemented into Wufi tools. That is possible because we compute the numerical model with data collected from the system investigated.

## II. SUPPLEMENTARY CEMENTING MATERIALS

### A. Fly Ash (FA)

FA as a by-product of coal combustion is a heterogenous material. The chemical properties of FA are influenced both by the characteristics of the coal burned and by the storage method. The addition of FA to the concrete has an impact on its behavior. The use of FA as supplementary material lead to the reduction of the hydration heat, and to the enhancement of the concrete mixtures fluidity at the fresh state [3], [10]. The setting time of cementitious mixes including FA is longer than the mixes without FA. This difference is due to the slow pozzolanic reactions of FA [3], [15]. Rashad shows that the increase of the substitution rate lead to a decrease of the drying shrinkage [3]. These findings are attributed to the densification of the matrix, which hinders the evaporation of water [15]. Concerning the thermal behavior of mixtures containing FA only few studies have investigated it. Nevertheless, it has been observed a reduction in the thermal conductivity of the mortar and concrete with FA [16]. The hydration reaction of FA is relatively slow, which explains why its contribution is not noticeable at younger ages [17]. Berry et al. [18] reported that the FA in the early stages act as a space filler, and that are implicated in the creation of ettringite (AFt). In the long term, they take part to the hydration reaction mainly as silico-aluminate binders. When materials rich in silica (SCM) are used, the reaction products,

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mainly in the form of Calcium Silicate Hydrates (CSH), show lower calcium-silica ratios (c/s) [19], [20]. Due to its slow hydration and necessity for activation, the use of FA in blended cement can improve age strength but lower early age strength. To improve the strength of ternary mixed cements at an early stage, efforts have been undertaken to incorporate carbonate. Different studies show that the combination of calcium carbonate, originating from limestone and FA in concrete or mortar is complementary. Indeed, the calcium carbonate filler improves the early strength of concrete whereas the FA improves the later strength and thus achieving an optimal strength development [19], [21].

### B. Ferronickel Slags

The FNS used are provided by The Société Le Nickel (SLN, New Caledonia) and have interesting properties such as low density, sufficient hardness and toughness, strong compaction potential, high water permeability, and great fire resistance with moderate thermal expansion [22]. SLN produces 3 million tons of FNS per year and has a stock of 25 million tons [22]. Only 8% of yearly FNS production is currently being utilized [23]. FNS have been shown to be unsuitable for structural usage in research over the last 50 years [23], [24], and there are just a few investigations on the use of FNS from New Caledonia in concrete. However, issues with durability have been reported [25]. As a result, the FNS are only used as a base filler for roads [25].

### C. Seashell Powder

Seashell is another potential waste product abundant in nature that can play the role of MSC. In Normandy (France), for example, scallops, oyster shells, crepidula, and mussel shells are available at high quantities. France is one of the largest consumers of shellfish in Europe. Each year, 191,800 tons of shells end up in landfills, incinerators or as waste in the coast in France [26]. Different studies on the use of shells as supplementary cementing materials have been ongoing for the past 50 years [27], [28]. These studies show that ground shells can be used in mortar and concrete. The partial replacement of cement by shells can present an adequate and lower thermal conductivity than the control mortar. The shells are composed of 95% of calcium carbonate ($CaCO_3$), which is similar to the calcium carbonate content of the limestone powder used for Portland cement production [29].

### III. RESULT AND DISCUSSION

In line with what is already proposed in the literature, the conceptual study plan of our work consists of three main parts, summarized as follows: In the first step, we substituted partially the cement by FNS and crushed CR and by FA and crushed CR and we investigated the mechanical behavior, in particular the compressive strength according to EN196-1 [30]. In the second step, we investigated the thermal conductivity of the mixed concretes with cement substitution by FA-CR. In the third and last step, we studied the hygrothermal behavior of the material.

### A. Compressive Strength

The compressive strength values of the mortars after a curing time of 2 days,7 days, 14 days and 28 days are presented in Fig. 1 and Fig. 2. For the mixes with cement substitution by FNS-CR (Fig. 1), the maximum compressive strength is observed for FNS-CR-10 and at the early age of 2 days. However, the compressive strength of mortars containing up to 20% FNS-CR is still more than half that of CM mortars. For the mixes with cement substitution by FA-CR (Fig. 2), the maximum compressive strength is obtained with 10% of cement replacement. Above 10% of FA-CR substitution (FA-CR-10), the results show that the compressive strengths decrease with the increase of the substitution rate. At a substitution level of 40%, the strengths are still adequate for application in the construction industry.
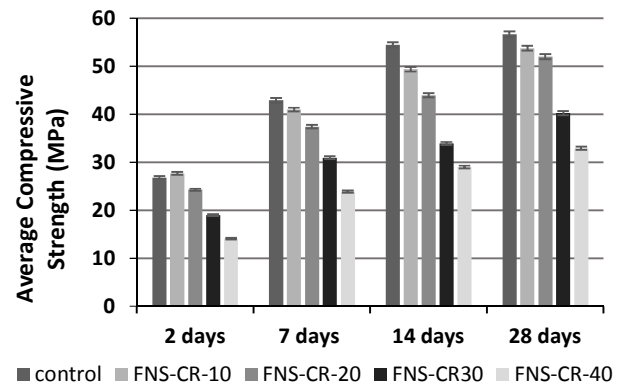


Fig. 1 Compressive strength of cement mortars with partial substitution by FNS-CR at 2, 7, 14 and 28 days
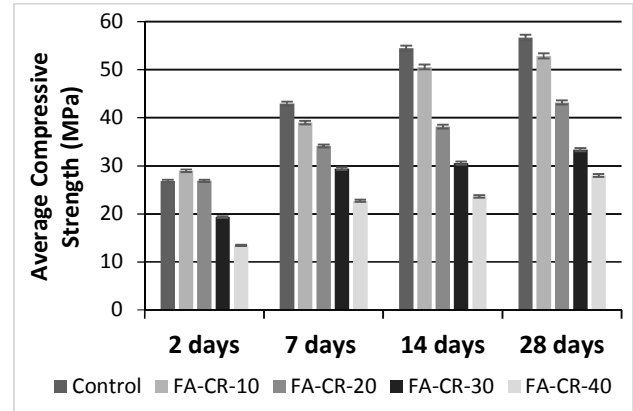


Fig. 2 Compressive strength of cement mortars with partial substitution by FA-CR at 2, 7, 14 and 28 days

### B. Thermal Conductivity

The thermal conductivities of all the FNS-CR mix are close and do not decrease, for this reason we have chosen to present in the following paper only the results of the FA-CR mixtures. Indeed, the concrete with FNS contains a large amount of Mg and Fe, which are very high-electronic-conductive elements.

For each substitution rate by FA-CR, a concrete specimen with dimension of 30 cm x 30 cm x 7 cm was prepared. The thermal conductivities of all mixtures were performed using a Heat Flow Meters (HFM). In the Fig. 3, we show that the thermal conductivity of concrete samples decreased with the increase of FA and CR amounts. The decrease in thermal

conductivity between the control concrete and the concrete with 10% of FA-CR is greater than the decrease noticed above 10% of substitution level. These initial results are of great interest and show that the addition of FA and CR can significantly reduce the thermal conductivity of concrete.
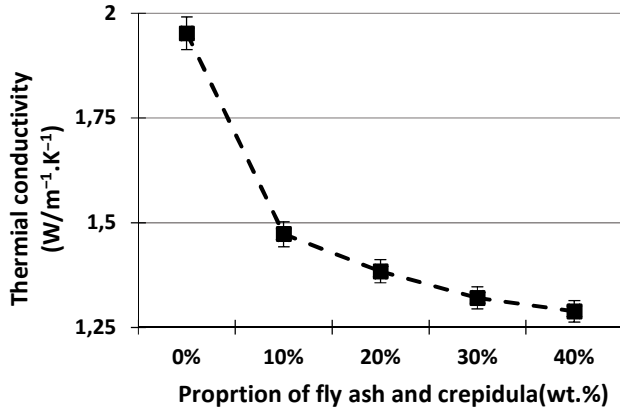


Fig. 3 Variation of thermal conductivity of different formulations after 28 days of cure

### C.    Artificial Neural Network

Finally, we used the FA-CR-30 optimal formulation for the rest of the study. Indeed, this mix has a mechanical strength similar to a CEM III 32.5 cement as well as a thermal conductivity, e.g., 30% lower than the ordinary concrete. To monitor the hygrothermal behavior of this formulation we built a prototype house of 70 cm long, 70 cm wide and 70 cm high (Fig. 4). The walls are made of 5 cm of concrete and 5 cm of external thermal insulation. As part of the reflective approach of recycling, we used panels of recycled cotton as insulation with a thermal conductivity of 0.039. We designed an opening of 30 cm ×25 cm to comply with the RE 2020 standard, which states that a Glazing of at least 16% of the living area must be applied [31]. In addition, we placed seven sensors of temperature and relative humidity, and one solar radiation sensor on different sides of the structure. Outside, we placed a temperature, a humidity, and a solar radiation sensor.
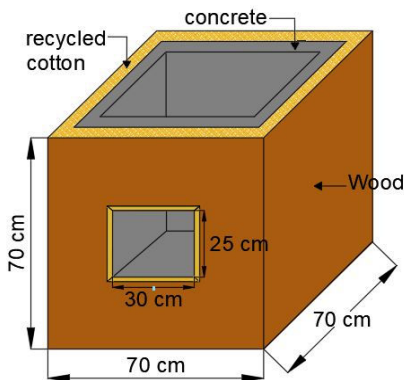


Fig. 4 Description of the prototype house

The data collected for 10 days from the sensors were used to train the data-driven model. The first step of the training is to choose the type of data that will enter the model training.

Among the input data used, we have the outdoor temperature, outdoor humidity and the concrete constituents. The outputs are the temperature and humidity inside the structure. We trained the model with 70% of the collected data and tested it with the remaining 30%. Fig. 4 shows the temperature and the relative humidity obtained by the neural network model as a function of the experimental values during the training, validation and global phases. The adequacy of the result predicted by the implemented model was evaluated by the statistical correlation coefficient (R) (Fig. 5).
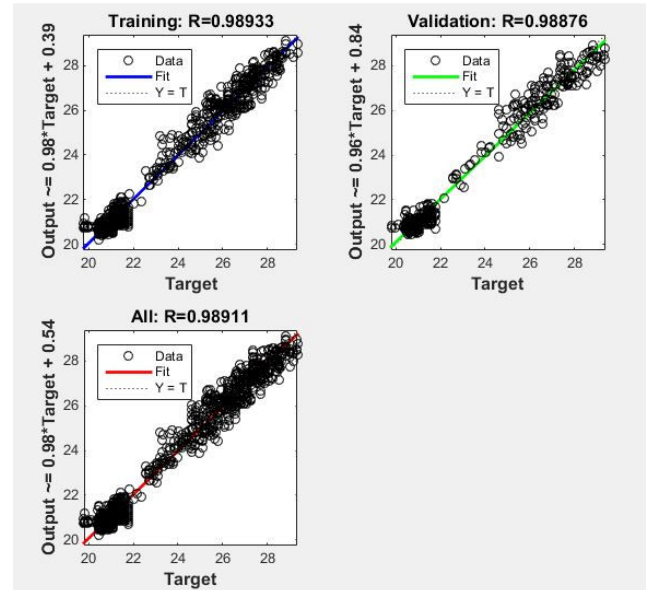


Fig. 5 Forecasted and experimental temperature values obtained for each phase of the model implementation

The statistical correlation coefficient is shown for each of the training, validation, and global phases. For the temperature prediction, we observe that the correlation coefficients for the training and validation data are 0.989 and 0.988 respectively. This result means that the estimated value from the input data agrees with the measured value.

### D.    Condensation

The Glazer technique is used to calculate the vapor pressure (Pv) and the internal saturation pressure (Ps), as stated by Nervetti and Soma [32]. The area of the prototype where (Pvint-Psint) is maximum presents the greatest risk of condensation and there is no risk of condensation if (Pvint-Psint) is always negative or equal to zero. Fig. 6 shows the condensation risk indicator, which is a function of the internal (Pv) and internal (Ps). In Fig. 6, it is observed that there is no risk of condensation inside the prototype since the Pvint-Psint values are consistently negative. This is due to the moisture absorption by the concrete mixture with FA-CR.
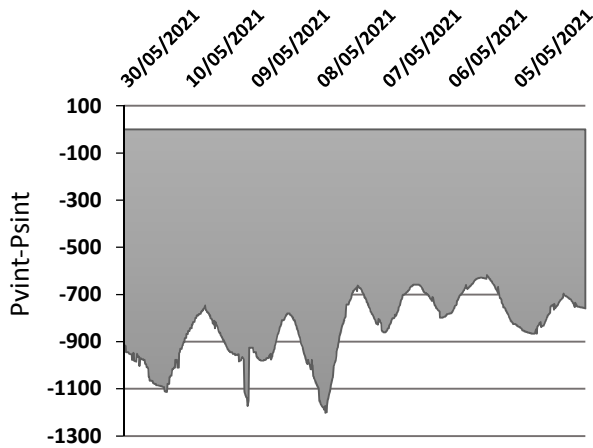
Fig. 6 Risk of condensation

Fig. 7 shows the compressive strengths of the concrete mixture with FA-CR-30 after 14 days, 28 days, and 300 days of curing time under controlled conditions. The compressive strength continues to increase with the age, this occurs due to the ongoing hydration of the cement. Indeed, by forming additional CSH and CSAH, the absorbed moisture contributes to the continued pozzolanic reaction of the concrete.
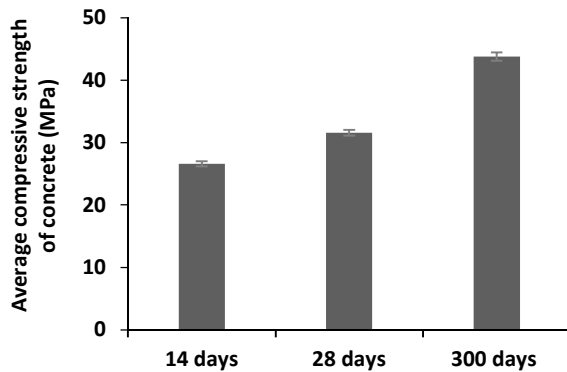


Fig 7. Compressive strength at 14, 28, and 300 days of the concrete CR-FA-30

## IV. CONCLUSION

The use of CR, FNS and FA will contribute in the accomplishment of sustainable development goals and in the reduction of carbon footprint. Our results show an acceptable behavior of the compressive strength with the substitution of cement by FNS-CR, and a significant improvement of the mechanical performance at 10% of cement substitution with FA-CR. Regarding thermal conductivity, we observed a significant decrease with the substitution increase. Based on the mechanical and thermal properties, the optimal formulation retained is with 30% of cement substitution. Then we evaluated the ability of the ANN model to predict the indoor temperature and relative humidity of the optimal concrete mix. The obtained coefficient of correlation is close to 1, which demonstrate a high accuracy of the neural model. Modeling with neural networks has proven to be a successful approach for achieving a good match between experimental and forecasted values.

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# An Ensemble-Based Method for Vehicle Color Recognition

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*Abstract*—The vehicle color, as a prominent and stable feature, helps to identify a vehicle more accurately. As a result, vehicle color recognition is of great importance in intelligent transportation systems. Unlike conventional methods which use only a single Convolutional Neural Network (CNN) for feature extraction or classification, in this paper, four CNNs, with different architectures well-performing in different classes, are trained to extract various features from the input image. To take advantage of the distinct capability of each network, the multiple outputs are combined using a stack generalization algorithm as an ensemble technique. As a result, the final model performs better than each CNN individually in vehicle color identification. The evaluation results in terms of overall average accuracy and accuracy variance show the proposed method's outperformance compared to the state-of-the-art rivals.

*Keywords*—Convolutional Neural Network, Ensemble Agorithm, Stack Generalization, Vehicle Color Recognition.

## I. INTRODUCTION

As the number of ground trips is expanding, Vehicles have become a necessity in modern human life. A growing number of vehicles, resulting in high accident rates, traffic congestion, pollution, etc., has increased the need for a system to control vehicles precisely. Currently, Intelligent Transportation System (ITS) has been developed to facilitate vehicle monitoring via reducing human intervention. ITS plays a vital role in reducing risks, accident rates, air pollution, and increasing safety and reliability [1]. One of the most common monitoring equipment is the camera-based imaging system. For vehicle monitoring based on recognition through imaging, the most important visual attributes of a vehicle like a license plate[2], [3], model [4], and color[5] are recognized from images taken by surveillance cameras. Vehicle recognition finds applications in a variety of fields such as traffic surveillance, parking management systems, law enforcement, and crime detection.

By detecting a license plate, identifying a vehicle is quite easy because the license plate is unique to each vehicle. However, in cases where the plate is not fully visible and has been tampered with or illegally replaced, other attributes like model and color might help identify a vehicle. Since color is an unconcealable feature of a vehicle, covers a large part of the body, and is less sensitive to viewpoint changes and partial occlusion, it can play a crucial role in visual vehicle recognition.

Color is proven to be an important feature in machine vision tasks (e.g., segmentation, object recognition, image retrieval). Unlike many other image features, color perception largely varies in outdoor and indoor scenarios. Since the environment (i.e., lighting, temperature, weather, number and type of objects, etc.) can be easily controlled indoors, indoor color recognition faces fewer challenges than its outdoor counterpart. However, in outdoor color recognition, we face extra challenges such as complex color backgrounds, the multiplicity of color objects, illumination variance, surface reflections, and extreme weather conditions. For instance, an image in hazy conditions contains white color noise, which can degrade the quality of the image. Moreover, in different lighting conditions, the perception of the color of the same object might vary significantly.

Since this paper focuses on vehicle color recognition, besides the outdoor challenges, many other complexities are also present due to mobility, car body material, and paint specifics. In particular, first, the vehicle images are prone to blurriness due to the relative movement and speed between the camera and the object. Second, the light reflections are more complex than many other objects because of the vehicle's metallic body, mirrors, and windows. Third, different vehicle paint types such as solid, metallic, matte, and pearlescent feature specific light reflections. Besides, color is generally a continuous concept, and a single color can have a wide variety of shades and tones, for instance, blue, dark blue, sky blue, navy. Regarding vehicle color recognition, the continuous concept of color should be represented by a limited number of discrete classes, which introduces some accuracy concerns into the system.

Generally, there are three main steps in vehicle color recognition:

1) **Preprocessing**: The preprocessing step is usually done to improve image quality by reducing the aforementioned adverse effects on color identification. Region of Interest (ROI) selection, adjusting the contrast, and haze removal are standard methods in preprocessing.

2) **Feature extraction**: Features can represent an abstraction of an image in space, herein, the color space, by preserving the essential characteristics of the image. Color spaces are essential means for showing the intensity and color information in an image. Various color spaces display color information in different ways, such as RGB, CIE-lab, and HSV. RGB is one of the widely used color spaces that present color as a combination of red, green, and blue. In CIE-lab, $l$ channel represents lightness information while $a$ and $b$ channels display color information. HSV is another one that has three components: hue, saturation, and value. Color information is represented in hue and saturation channels, while the value channel contains intensity information. Unlike RGB, the color information is separated from the luminance in HSV and CIE-lab [6]. Handcrafted (e.g., histograms) and automatic

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(e.g., Neural Networks) feature extraction methods are two main ways of information eliciting.

3) **Color classification**: Classification is the last step in vehicle color recognition, which is done using machine learning algorithms such as Support Vector Machines and Neural Networks.

The rest of the paper is as follows: We start with motivation and Contributions in section II. The related works are studied in section III. The proposed method is explained in detail in section IV. Evaluation of the proposed methodology and comparison with the state-of-the-art methods are presented in section V, followed by concluding remarks in section VI.

## II. MOTIVATION & CONTRIBUTIONS

Using image processing techniques to improve the quality of images is recommended to control the challenges of vehicle color recognition. Extracting various high-level features from images is also a practical way for recognition purposes. Artificial Neural Networks have proven to be a strong tool for feature extraction. Recent studies [5], [7], [8] use only a single Convolutional Neural Network (CNN) for extracting vehicle color features from images. On the same note, intending to find a high-performance vehicle color recognition CNN, we designed several CNNs with different architectures whose parameters are determined by trial and error. As the sketchy drawing of Fig. 1 suggests, one important observation is that different CNNs with almost the same average accuracy deliver different color-specific accuracies. This observation motivates us towards devising a system that can make a synergy between separately trained individual classifiers.

In the related literature, ensemble algorithms are used to combine machine learning models at different levels (that is, feature fusion and output fusion)(see Fig. 2) [9]. In this work, we employ an output-fusion-level ensemble algorithm that combines the outputs of separately trained multiple CNNs with complementary color-class-span performance for the first time. In other words, the individual CNNs are configured so
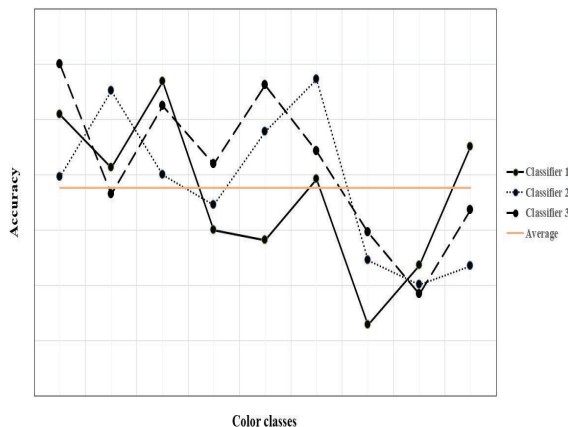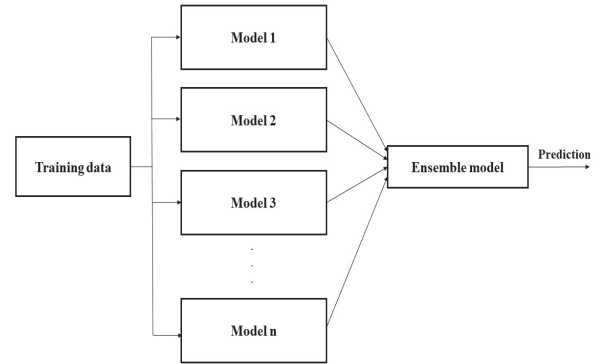


Fig. 2: Ensemble algorithms architecture.

that their combination provides a good synergy and increased average accuracy compared to the individual ones.

The highlights of the work in this paper are as follows:

- Using multi-CNN rather than single CNN for feature extraction and preliminary classification and configuring them with complementary accuracy over the color class span.
- Employing the stack generalization algorithm for final ensemble classification.

## III. RELATED WORKS

Preliminary research on vehicle color recognition has been performed using handcrafted features. Handcrafted features such as color histograms [10], color moment [11], color correlogram [12], etc., are used to represent the color characteristic in images.

Nakhoon Baek et al. [13] use the HSV color space to overcome the intensity variation issue. The $H$ and $S$ values are calculated in the vehicle area, and a two-dimensional histogram is obtained for the SVM color classification. Yi-Ta Wu et. al uses a model-based background subtraction algorithm and image segmentation to obtain a suitable area for feature extraction [14]. 2D histograms of $H$, $S$, and $V$ color channels are obtained as features. Then, a multi-layer SVM is performed for color classification. Yu-Chen Wang et al. [15] combine the histograms of six color spaces, use a manifold learning algorithm to reduce high feature dimensions, and employ a multi-class SVM to produce their best results. Pan Chen et al. [10] propose Feature Context (FC) to select the ROI in the vehicle image. Different color histograms are combined, and the Bag of Word (BoW) model is adopted to represent the color information. Finally, these features are learned using linear SVM.

All of the abovementioned works have been done using handcrafted features. With the help of handcrafted features, good accuracy will be obtained under simplistic assumptions, but it cannot be generalized to complex real-world scenarios, leading to unsatisfactory results. Also, designing and implementing these features require the supervision of skilled human operators.



Fig. 1: Typical color classifiers' accuracy performances.

Another group of deep-neural-network-based methods that automatically extract features without human intervention has emerged to recognize the vehicle color more efficiently. The CNN is a deep model that can automatically extract various features from the raw data [16]. This kind of network has high computational complexity. However, its advantages, such as extracting features adapted to each task, robustness in complex settings, high generalization capability, and reduction of human faults, outweigh the shortcoming.

Chuanping Hu et. al combines the spatial pyramid strategy and CNN to extract the optimal features to feed the SVM classifier[17]. Before introducing them to the network, Reza Fuad Rachmadi et al. [18] convert the input images into two different color spaces, HSV and CIE Lab. The network is the combination of two basic CNNs. Zhang et. al.[8] utilizes a CNN architecture as a feature extractor. The feature space dimension is then reduced, using the Principal Component Analysis (PCA) method, before applying an SVM classifier. Zhang Qiang et al. [7] employ a lightweight CNN for color recognition. Lightweight means that the number of layers in this network, five, is less than the layer multiplicity in other typical networks. Moreover, as opposed to the common practice wherein the features extracted in the last layer are used for classification, this work also considers the hidden layers' features based on residual learning. Huiyuan Fu et al. [5] introduce the Multiscale Comprehensive Feature Fusion Convolutional Neural Network (MCFF-CNN) for color features extraction, followed by SVM for vehicle color detection.

By comparing the two mentioned sets of feature extraction methods, CNNs show stronger learning capability and higher robustness in noisy conditions due to extracting more useful features, which in turn, lead to a more precise color classification. The latter motivates us to apply CNNs for feature extraction and color classification. However, a single CNN performs non-uniformly over different color classes. To overcome this deficiency, we propose multiple CNNs, each performing better in some classes than the others. Then, the outputs of the CNNs are combined using some ensemble algorithms (e.g., [19], [20]) to achieve a per-class, and in turn, overall increased accuracy.

## IV. METHODOLOGY

The three main steps of the proposed method are as follows:

1) **Preprocessing**: Brightness adjustment is performed to reduce the environment interferences.
2) **Multi-CNN training**: A group of CNNs (four herein) with different architectures are trained with the same dataset as preliminary classifiers.
3) **Ensemble Neural Networks**: The outputs of preliminary classifiers are combined using the stack generalization algorithm [21].

The process of vehicle color recognition using the proposed method is depicted in Fig. 3. A detailed description of each step comes shortly.

### A. Preprocessings

The preprocessing step of the proposed method includes Brightness adjustment.

The color perception of an object is highly dependent on the related image's illumination intensity. The adverse impact of extreme illumination is highlighted in the case of close colors. Hence, to reduce the illumination-based adverse effects, the image brightness adjustment is performed if needed.

The brightness adjustment (i.e., increase or decrease) on each image is performed as per $NewCol_i = Col_i \times \alpha \pm \beta, \quad i = r, g, b$ wherein $NewCol_i$ and $Col_i$ are post adjustment and pre-adjustment colors, respectively [5]. The parameters $\alpha$ and $\beta$ are the adjustment parameters that are specific to the employed dataset.

### B. Training Multiple CNNs

The advent and development of digital image acquisition tools, particularly mobile devices, have led to a dramatic growth of image data. Extraction of meaningful information from large volumes of available images makes the image classification and recognition very important subjects of interest. Machine learning methods, and its more recent subsidiary, deep learning algorithms, especially CNN, have long proved useful in image classification and recognition.

CNN consists of several convolutional layers that are consecutively placed. Each layer extracts the important features and information of the input image by applying proper filters. The extracted features are fed to the next layer in the form of feature maps. The pooling layers are placed between convolutional layers to reduce the dimensions of the feature maps. Max pooling is one of the common types of the pooling layer, which calculates the maximum value for each patch in the feature maps. Finally, a fully connected layer (as the last layer of CNN) aggregates the information from the final feature maps and performs the classification. The size and configuration of the employed filters are performance-determining factors in different applications, resulting in different variants of CNN.

Since feature extraction is done automatically without human intervention, the learned features in a neural network are not tractable. To extract more diverse features and increase the neural network's learning ability, we employ an inception module in some of the neural networks in the proposed system. The inception [22] is a block of several convolutional layers with different filters that provide learning at multiple scales in parallel, as shown in Fig. 4. Each trained CNN, based on the number of layers embedded and whether it employs the inception, generates different accuracies over different color classes. To benefit from each class performance's strengths and avoid weaknesses, we combine (ensemble) the outputs of trained networks.

### C. Ensemble Neural Networks

As mentioned in section II, fusion can be done at two levels: features fusion and outputs fusion. In feature fusion, the primary purposes are features reduction and noisy features
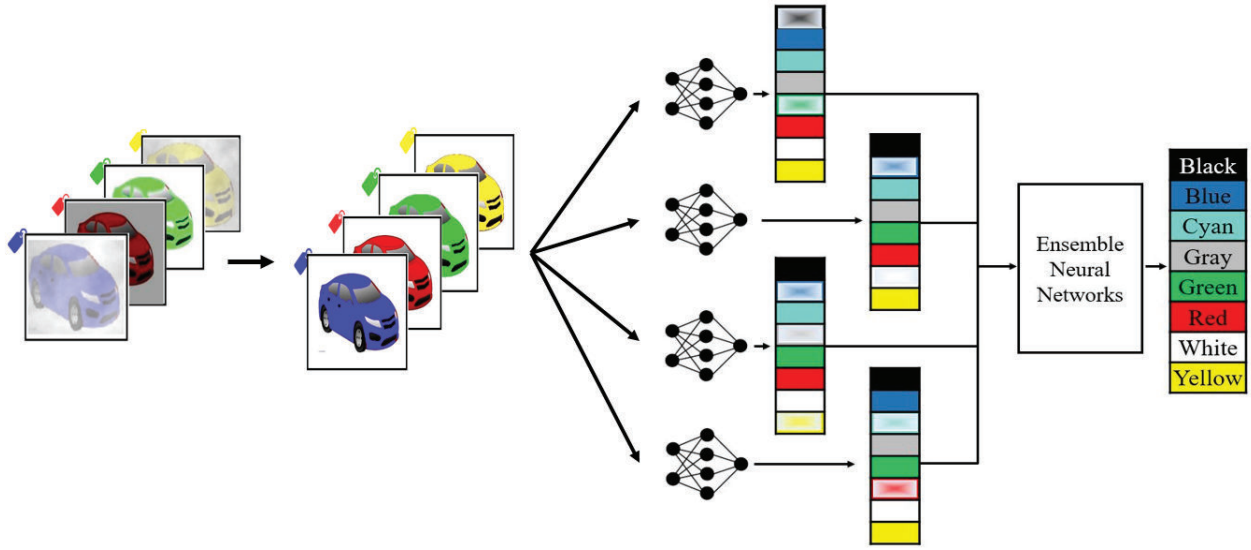
Fig. 3: Proposed method's architecture.
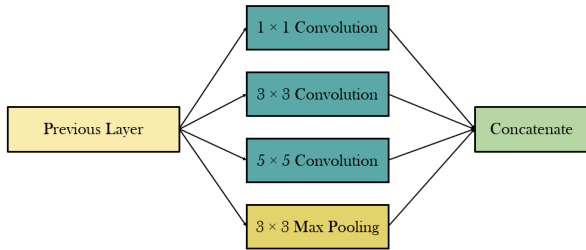


Fig. 4: An inception module with three convolutional and one max pooling layers.

elimination. There are generally four steps in features fusion: feature ranking, feature selection, feature extraction, and feature combination. Ranking, selection, and extraction help choose the best features and remove the redundant ones. Feature combination, which includes parallel or serial combinations, combines the selected features [23].

Improving the performance and accuracy of deep models has always been a major challenge. Ensemble algorithms are one of the effective output fusion techniques to improve the performance of trained models [24]. Unlike the usual learning methods that build a single model to solve the problem, Ensemble methods develop a set of already trained models that synergically generate a higher accuracy than each constituent model. Thus, these methods have been proposed to provide a strong learner using a set of less strong learners. There are a variety of ensemble algorithms in the literature:

- Voting: It is one of the simplest ensemble techniques in which the final output is obtained by voting from base learners' output[25]. A newer version of this algorithm is weighted voting which assigns a weight to each base learners' output according to its accuracy performance. However, since constant weighting cannot reflect the

class dynamics of the classifier, in some cases, the final improvement is compromised [26].
- Bagging: In this method, the training dataset is divided into multiple not-necessarily separated parts. Then, each model is trained using only one part, and the outputs are combined based on voting [27].
- Boosting: Multiple models are trained sequentially using the same training dataset. Thus, each model is trained to correct the false predictions of previous models by assigning higher weights to falsely predicted samples [28].
- Stacking: Several models are trained using the same dataset. Then, another model is used to learn how to combine the predictions of previous models better. The good point about the stacking algorithm is that it adapts itself to the predictions of models over the introduced samples [21].

In this paper, we employ the stack-generalization ensemble algorithm in which a meta learner (e.g., KNN and SVM) is trained to combine the predictions of two or more models. The meta learner in our proposed vehicle color recognition method is a Multi-Layer Perceptron(MLP) which combines the outputs of the possibly weak separately-trained CNNs. For training the meta learner, the training set is divided into $K$ folds, from which $K-1$ folds are used to train the CNNs. This process is repeated $K$ times with a new permutation of folds. Then, a new numerical dataset is constructed by appending the probabilistic predictions (called metadata) of the CNNs on the $K$th fold and its already known labels. Finally, the meta learner is trained by the as-such-constructed dataset to recognize the vehicle's color.

The final proposed architecture for vehicle color classification, presented in Fig. 5, ensembles the resulting outputs of CNNs with different numbers of layers w/wo inception employment using the meta classifier.
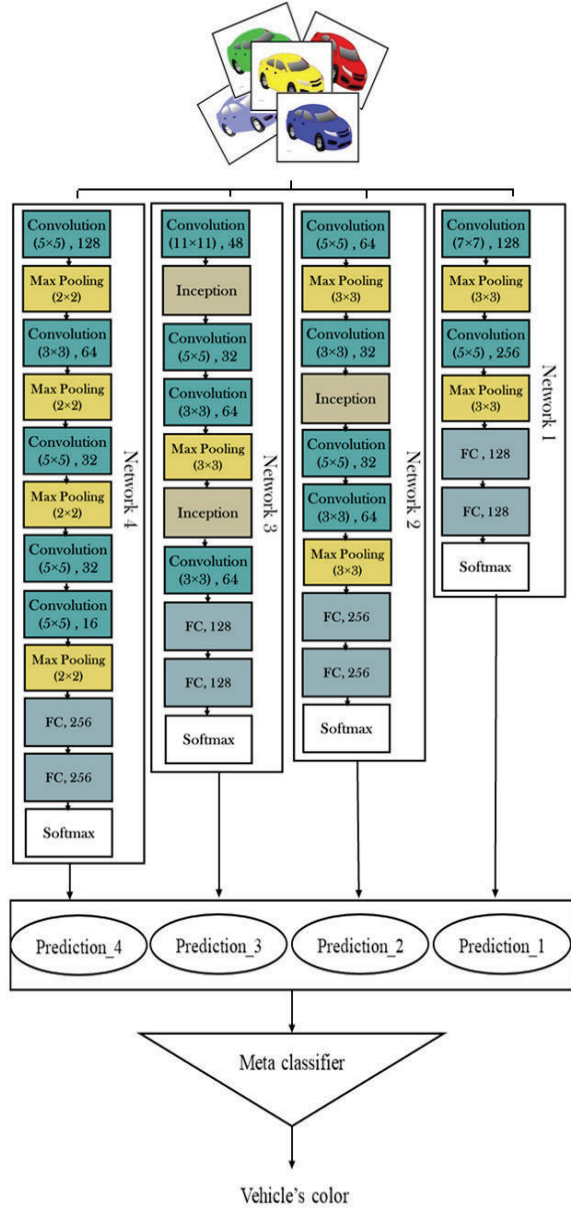
Fig. 5: Architecture of the method with detailed CNN configurations.

## V. Performance & Evaluation

This section presents the results of the experiments and comparisons with related works in vehicle color recognition. First, we start by introducing the employed dataset, which is widely used in other related works. Then, we examine the performance of our method using the mentioned dataset. Next, we present the proposed method's implementation details, and then the generated experiments results are presented and discussed.

### A. Dataset

The widely-used vehicle color dataset, provided by one of the authors of [10], includes 15601 images in eight colors: black, blue, cyan, gray, green, red, white, and yellow. The dataset images contain only a single vehicle taken from the front view of various vehicles, including trucks, buses, and cars, in different weather conditions and illumination levels.

### B. Implementation Details

We generated vehicle color classification using four networks called Network-1 (with the lowest number of sequential convolutional and pooling layers) to Network-4. In addition, Network-2 and Network-3 include embedded inception modules as well. The architectures and specifics of the four networks are illustrated in Fig. 5.

The input is an RGB vehicle image with the size of $224 \times 224 \times 3$. The outputs of the convolutional layers are remodeled using Rectified Linear Unit (ReLU) activation function and then normalized to avoid saturation, using batch normalization. We use max pooling for the pooling layer, which reduces the number of parameters and computations in CNNs. The last three layers are fully connected. With softmax activation function, the final layer is responsible for the classification, herein a vector of size $8 \times 1$ that probabilistically predicts the vehicle color. Additionally, Stochastic Gradient Descent (SGD) is selected as the optimizer for updating the parameters of CNNs during the training phase.

To fairly compare the proposed method with the related works, the same following settings have been considered for all: fifty percent of the dataset is used for training and the rest for testing. As shown in figure 6, the training set is divided into six equal folds from which a selection of five folds are used to train the preliminary classifiers. The sixth one is employed to construct a new dataset for the meta classifier training explained before. The procedure is repeated six times, each time with a new five-fold selection. The final accuracy result is the average of the obtained accuracies in each run.

### C. Experimental Results & Discussion

First, using the dataset of [10], the average accuracy results of the four proposed networks and their ensemble are presented. Then, the results of the proposed method are compared with the state-of-the-art related works in this field.

The test results of the four trained CNNs (i.e., Network_1 to Network_4), using the first five-fold permutation (i.e., folds 1, 2, 3, 4, 5), and their ensemble according to Fig. 6 is shown in table I.

The table highlights the maximum and minimum accuracy among the four networks in recognizing different colors in green and red, respectively. There are two main observations from the results in table I. First, the performance results of each network vary in different color classes. A network might show good accuracy in one or several classes while not performing well in others. Second, the performance variations of networks show some form of synergy which can be taken advantage of. Figure 7 provides an accuracy-based ranking
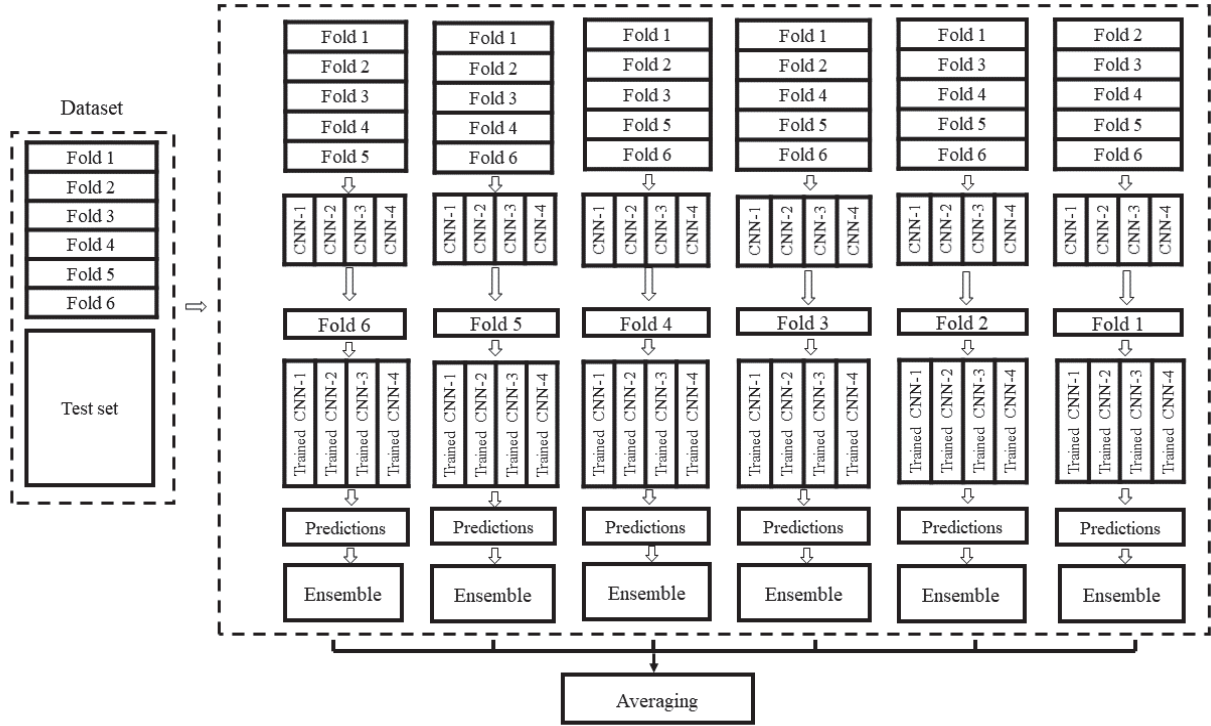
Fig. 6: Data flow details of the training and test phases.

TABLE I: Performance results of four individual CNNs and their ensemble.

| Model | Average Accuracy | Black | Blue | Cyan | Gray | Green | Red | White | Yellow |
|---|---|---|---|---|---|---|---|---|---|
| Network-1 | 0.9617 | 0.9914 | 0.9667 | 0.9928 | 0.8498 | 0.9704 | 0.9917 | 0.9453 | 0.9861 |
| Network-2 | 0.9524 | 0.9419 | 0.9593 | 0.9785 | 0.9354 | 0.9556 | 0.9866 | 0.9006 | 0.9619 |
| Network-3 | 0.9580 | 0.9709 | 0.9574 | 0.9928 | 0.8645 | 0.9753 | 0.9907 | 0.9436 | 0.9688 |
| Network-4 | 0.9528 | 0.9840 | 0.9778 | 0.9928 | 0.8856 | 0.9408 | 0.9948 | 0.8611 | 0.9861 |
| Ensemble | 0.9696 | 0.9886 | 0.9778 | 0.9928 | 0.8952 | 0.9753 | 0.9917 | 0.9574 | 0.9784 |

of the single CNN and multiple CNN networks. Therefore, the proposed ensemble model using the stack generalization algorithm can benefit from the observed synergy. The ensemble model outperforms each of the four networks individually, providing high accuracy in most colors.

In table II, the final accuracies (i.e., the average of six times repetition, each time with a new five-fold selection) for each color class, the over-classes-average accuracies, and their corresponding variances obtained by the proposed method are presented and compared with other state-of-the-art related works. There are two main observations regarding table II: the proposed method outperforms all other methods. Furthermore, which is even more important than the first observation, the class-specific performances are less fluctuated, represented by

the lower accuracy variance, in the proposed method, thanks to the ensemble algorithm employment.

## VI. CONCLUSION

This paper presents a novel method for vehicle color recognition using ensemble algorithms for the first time in this field. The conventional methods use a single neural network for feature extraction and classification. However, combining the outputs of multiple neural networks with various architectures via stack generalization algorithm proves capable of performing the challenging task of vehicle color recognition with inherent complexities. The evaluation results confirm that a reasonable balance between overall and class-specific accuracies in recognizing different colors is achieved.
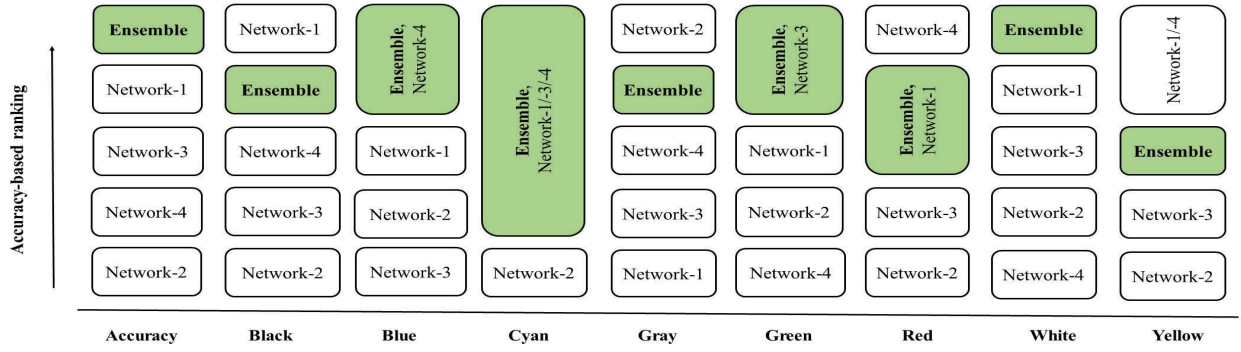
Fig. 7: Accuracy-based ranking of single CNN classifiers and the multiple CNN network (ensemble).

TABLE II: Comparison of the proposed method with related works in recognizing different colors.

| Model | Variance | Average Accuracy | Black | Blue | Cyan | Gray | Green | Red | White | Yellow |
|---|---|---|---|---|---|---|---|---|---|---|
| P.Chen et al. [10] | 0.0051 | 0.9249 | 0.9713 | 0.9451 | 0.8461 | 0.7834 | 0.9876 | 0.9787 | 0.9414 | 0.9457 |
| R.F.Rachmadi et al. [18] | 0.0036 | 0.9447 | 0.9738 | 0.9410 | 0.9645 | 0.8608 | 0.8257 | 0.9897 | 0.9666 | 0.9794 |
| Q.Zhang et al. [7] | 0.0023 | 0.9541 | 0.9756 | 0.9834 | 0.9857 | 0.8884 | 0.8672 | 0.9938 | 0.9629 | 0.9759 |
| Proposed method | 0.0011 | 0.9688 | 0.9869 | 0.9826 | 0.9828 | 0.8901 | 0.9749 | 0.9952 | 0.9587 | 0.9797 |

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# Analyzing the Oil and Gas Exploration Opportunities in Poland: Five Prospective Areas Selected and Dedicated to the Tender

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***Abstract***—Polish Geological Survey selected five of the most prospective areas for oil and gas exploration in Poland. They are dedicated to the 6th international tender round for hydrocarbon concessions, planned in 2022. The main exploration target of these areas is related to conventional and unconventional accumulations of gas and oil in the Carpathian basement, Carpathian Foredeep and Outer Carpathians (Block 413 – 414), as well as in the Carboniferous, Rotliegend, Main Dolomite (Block 208, Cybinka – Torzym, Zielona Góra West), and in the Mesozoic of the Polish Lowlands (Koło).

***Keywords***—concession policy, international tender, oil and gas exploration horizons, prospective areas.

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# Unlocking New Room of Production in Brown Field; Integration of Geological Data Conditioned 3D Reservoir Modelling of Lower Senonian Matulla Formation, RAS Budran Field, East Central Gulf of Suez, Egypt

Nader Mohamed

***Abstract*—** The Late Cretaceous deposits are well developed through-out Egypt. This is due to a transgression phase associated with the subsidence caused by the neo-Tethyan rift event that took place across the northern margin of Africa, resulting in a period of dominantly marine deposits in the Gulf of Suez. The Late Cretaceous Nezzazat Group represents the Cenomanian, Turonian and clastic sediments of the Lower Senonian. The Nezzazat Group has been divided into four formations namely, from base to top, the Raha Formation, the Abu Qada Formation, the Wata Formation and the Matulla Formation. The Cenomanian Raha and the Lower Senonian Matulla formations are the most important clastic sequence in the Nezzazat Group because they provide the highest net reservoir thickness and the highest net/gross ratio. This study emphasis on Matulla formation located in the eastern part of the Gulf of Suez. The three stratigraphic surface sections (Wadi Sudr, Wadi Matulla and Gabal Nezzazat) which represent the exposed Coniacian-Santonian sediments in Sinai are used for correlating Matulla sediments of Ras Budran field. Cutting description, petrographic examination, log behaviors, biostratigraphy with outcrops are used to identify the reservoir characteristics, lithology, facies environment logs and subdivide the Matulla formation into three units. The lower unit is believed to be the main reservoir where it consists mainly of sands with shale and sandy carbonates, while the other units are mainly carbonate with some streaks of shale and sand. Reservoir modeling is an effective technique that assists in reservoir management as decisions concerning development and depletion of hydrocarbon reserves, So It was essential to model the Matulla reservoir as accurately as possible in order to better evaluate, calculate the reserves and to determine the most effective way of recovering as much of the petroleum economically as possible. All available data on Matulla formation are used to build the reservoir structure model, lithofacies, porosity, permeability and water saturation models which are the main parameters that describe the reservoirs and provide information on effective evaluation of the need to develop the oil potentiality of the reservoir. This study has shown the effectiveness of; 1) the integration of geological data to evaluate and subdivide Matulla formation into three units. 2) Lithology and facies environment interpretation which helped in defining the nature of deposition of Matulla formation. 3) The 3D reservoir modeling technology as a tool for adequate understanding of the spatial distribution of property and in addition evaluating the unlocked new reservoir areas of Matulla formation which have to be drilled to investigate and exploit the un-drained oil. 4) This study led to adding a new room of production and additional reserves to Ras Budran field.

***Keywords*—** geology, oil and gas, geoscience, sequence stratigraphy.

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# Selecting Optimal Distance Between Wells In Sagd And Vapex Methods Using Reservoir Simulation

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*Abstract*— Nowadays, energy resources become difficult to extract and are known as non-renewable energy, it used new technology to enhance and improve the production rate. Non-renewable energy is the most and largest demand all around the world. The main task for this project is to enhance the production of heavy oil reservoirs by SAGD and VAPEX methods, taking consideration of the economic aspects of this project. Moreover. this project has been analyzed the SAGD method in the shallow reservoir which was the RF 69.8%, and in the deep reservoir was 38% which is very low recovery due to the heat loss affecting this process. Furthermore, has been analyzed the VAPEX method to aim the second objectives, it has been found the MMP by using the Slim Tube test and WinProp test, the MMP was at 3000 psi. In additional has been used the PROSPER Software to find the maximum depth to apply the SAGD method which was 3500ft. Based on the calculation from software has been found the heat loss for this reservoir round 350□ Third objective was achieved by analyzing and comparing the results of VAPEX method and SAGD method, the cumulative oil production of SAGD method in shallow reservoir was $3.87 \times 10^6$ bbl, and deep reservoir was $2.1 \times 10^6$ bbl, and for the VAPEX method at the shallow reservoir was $2.74 \times 10^6$ bbl, and at deep reservoir around $2.64 \times 10^6$ bbl, based on the results of each method the VAPEX method remain with same quality at both reservoirs, however the SAGD has the lower production in deep reservoir which means this method is not suitable for deep reservoir. Furthermore, has been calculated the profit of each method, the profit of SAGD and VAPEX were (190.97 MM$ & 168.97 MM$) at the shallow reservoir, and (72.97 MM$ 162.32 MM$) at the deep reservoir for each process. Finally, the spacing between injection and production wells was tested with different distance and the best distance was 30m. Last but not least, the VAPEX process proved to be very efficient and environmental.

**Keywords:**
ANN: Artificial Neural Network
SAGD: Steam Assisted Gravity Drainage
VAPEX: Vapor Assisted Petroleum Extraction
EOR: Enhanced oil recovery
IOR: Improve Oil Recovery

COP: Cumulative oil production
NPV: Net present value
CMG: Computer Modelling Group
FCD: Flow Control Device
RF: Recovery Factor
WC: Water Cut
MMP: Minimum Miscibility Pressure
CSS: Cyclic Steam Stimulation
SE-VAPEX: Single Vapor Assisted Petroleum Extraction

## I. INTRODUCTION TO THE STUDY

There are many of the reservoirs that have been discovered which are heavy oil, so the heavy oil attracts global attention which the volume of oil in place is huge.

However, there are many commercial operation challenges to extract the hydrocarbon, in this project will extract heavy oil which has a higher viscosity and density, these some of the challenges part that will face the petroleum engineer. Enhance oil recovery is used to optimize the production by using different methods, the most common methods are steam injection, chemical injection, and water flooding. In this project will use SAGD and VAPEX methods which is one of the steam injection methods. During the startup and early operation of horizontal SAGD wells, it is important to understand the flow distribution of bitumen and water along with the horizontal reservoir interval. If this distribution is understood, the distribution of steam, injected either at the heel or toe of the steam injector can be adjusted to optimize the startup and early operation of the SAGD pair

Furthermore, these methods make the immovable crude oil moveable. Today the energy sources become very tricky to get, the EOR and advanced level of the technology in the world and the nonrenewable energy (oil and gas) industry is the largest demand of energy generation. Consequently, Enhance Oil Recovery is used to extract and increase the production rate.
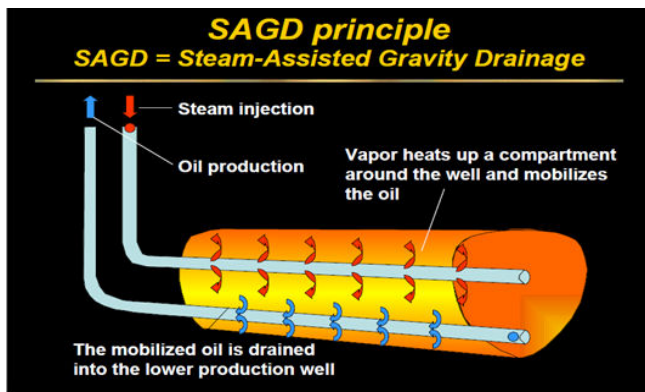
Figure 1: SAGD method (Afework et al., 2018) {1}.

Nowadays there are several methods used to extract heavy oil, in this project is used Steam-Assisted Gravity Drainage (SAGD) and Solvent Vapor Extraction (VAPEX) methods to produce heavy oil.

The SAGD method is show in Figure 1, moreover SAGD method has a high recovery, however, there are disadvantages in this process such as handling water and more water required to apply this method which will result $CO_2$ emission (Afework et al., 2018) {2}.

VAPEX method also has some challenges as well such as potential sensitivity to reservoir heterogeneity and low production rate. The VAPEX method use in the deep reservoir, so there is no heat loss such as the thermal method. VAPEX methods is show in Figure 2.
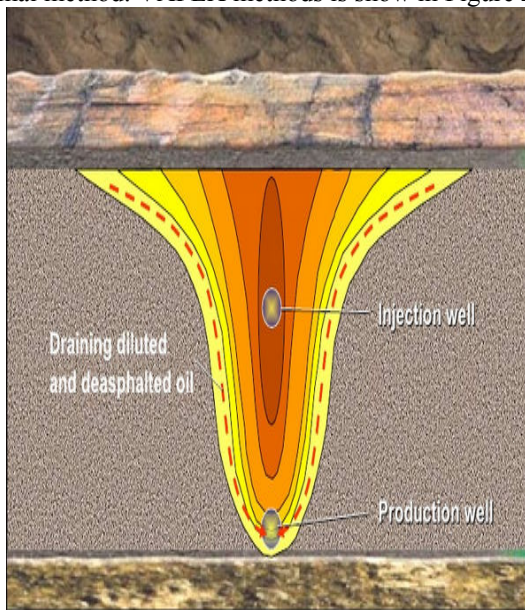


Figure 2: VAPEX method (Afework et al., 2018) {3}.

## II. PROBLEM STATEMENT

Nowadays the hydrocarbon reserves and the challenges to get other resources of energy that can be compared with fuel energy, as the world reserves are declines during the past years this is one of the problems which may happen in future. In this case, has been developed new technology to extract the hydrocarbon from the reservoir. In this project will be used two methods which use to produce heavy oil those methods are SAGD and VAPEX methods. There are some problems may happen in this project which will obstruct to achieve the objective.

The first problem is when build the model will have some errors in the component panel by using the CMG software, so should inter the PVT data carefully with avoiding any problems which may affect in the result.

The second problem is when will build the VAPEX model at the GEM will have some errors in the component panel as well similar to the SAGD method which used in STAR (Afework et al., 2018) {4}.

The third problems perhaps happen when finding the optimum depth to switch from SAGD and VAPEX, this section will be the hardest part which use sensitivity analysis to find in which depth SAGD will have heat loss, it difficult to find the exact heat loss, however, is not possible (Khan & Awotunde, 2016) {5}.

In last problems which may face is the will spacing and the number of wells which will increase the cost of the methods, so have to do different scenario of will spacing to the proper distance between the injection and production wells to be used in this project.

## III. OBJECTIVES

The aim of this study is to justify best distance between injection and production wells in SAGD and VAPEX processes by reservoir simulator and then to decide where the suitable distance required to apply those methods

The objectives of this study are:

1. To construct SAGD model based on the real data and find the best distance between injection and production wells when applying the SAGD method.
2. To construct a VAPEX model based on the real data and obtained the suitable distance between injection and production wells in VAPEX method
3. To analyze the results of SAGD and VAPEX methods in both reservoir shallow and deep based on real data

## IV. LITERATURE REVIEW

In this article, it shows the minimum well spacing required for horizontal wells to apply these process and success. From the results has been found the enhancement by using the SAGD and VAPEX is good.

Well, spacing technique constraints is important while utilizing this process. A well spacing is supported the penalty approach, which use to constrain wells in the reservoir (Khan & Awotunde, 2016) {6}.

### Problem formulation

SAGD and VAPEX methods have two wells in a parallel to each other. thus, use to optimize the production, we change and enhance the location of the well by different scenario we can get better results. Moreover, there are some of the limitation and problems which may affect this method, first of all, they must do screening criteria if the for-reservoir characteristics and oil properties are suitable for these methods then they have to select the best location

to drill the horizontal well with proper spacing to be more effective in this project (Khan & Awotunde, 2016){7}.

In additional in this article, has not explained about the equipment which is required to apply this method, and also the cost analysis for each method is not mention, to know if the methods are profitable or not, if it is profitable will considered as successful processes.

**Methodology of this article**

First of all, it has created the model by CMG simulator, then it shows the reservoir with distributed permeability field used for numerical simulation in the SAGD and VAPEX process. the distribution of the model is:

$32 \times 32 \times 10$ grid cells.

The dimension for X, Y, and z-direction is 200ft,200, and 8.2ft, the porosity for each model is different within each layer constant, the distribution porosity and permeability are shown in Figure 3 & 4 (Khan & Awotunde, 2016) {8}.
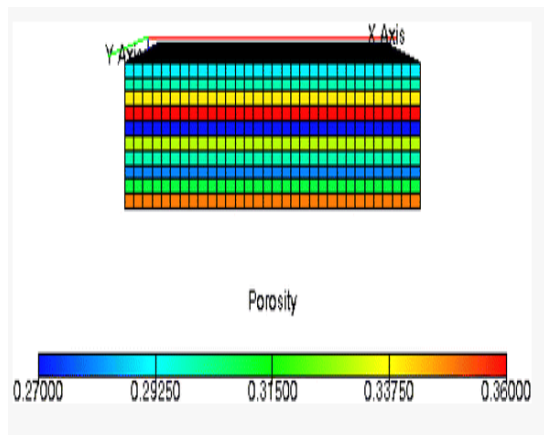


Figure 3: Porosity distribution (Khan & Awotunde, 2016) {9}.
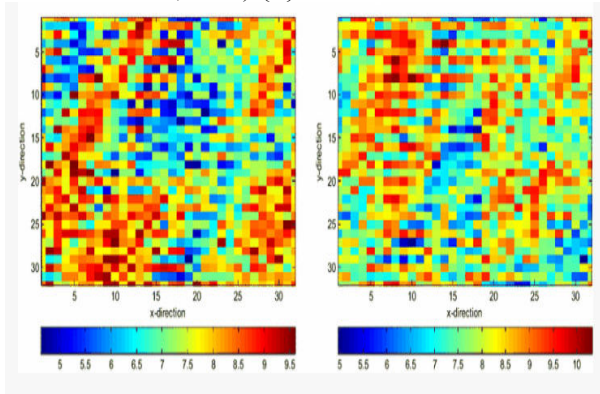


Figure 4: Permeability distribution (Khan & Awotunde, 2016) {10}.

After that, it shows the fluid-rock properties as shown in Figure 5, both production of the SAGD and VAPEX are in ten years. the steam quality for SAGD is 85% (Khan & Awotunde, 2016){11}.
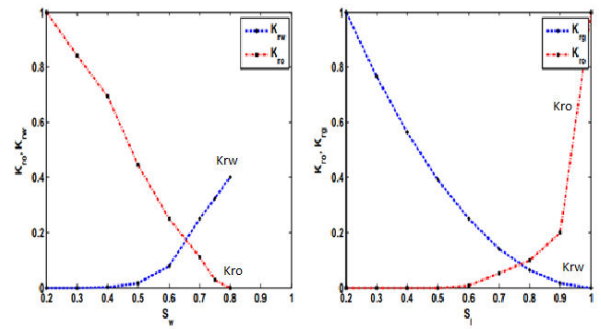


Figure 5: Relative permeability for SAGD and VAEPX

(Khan & Awotunde, 2016) {12}.

The SAGD method becomes more useful for heavy oil, so the economics part of SAGD process is very sensitive that's why will use the FCDs for steam efficiency, deliver and for utilize with successful SAGD pair wells is supported by how the thermal efficiency inefficiencies and can be mitigated in the profit of this process.to enhance the profile of SAGD will test with flow control devices (FCDs) (Hascakir, 2018) {13}.

**Limitation and problems**

It has summarized the strength and weakness of the present FCDs for SAGD use tables. The table 1 summarizes the operational strengths and weakness of all FCD geometry categories for the SAGD application (Hascakir, 2018) {1}.

Table 1: Summary of commercially available FCD designs (Hascakir, 2018) {14}.

| Geometry | Mechanism of action | Strengths for SAGD applications | Weakness for SAGD applications |
|---|---|---|---|
| Channel-style FCD | Frictional drag | Low risk of plugging or erosion May control steam flashing No moving parts | Sensitive to flowing fluid viscosity |
| Restriction-style FCD | Bernoulli principle | Inexpensive No moving parts | Significant risk of plugging or erosion May cause steam flashing |
| Autonomous FCD | Varied | Additional steam trap control | Varied |

The FCD flow control was used to regulate the production profile of SAGD method. The gap in this research which is the methodology of the SAGD method and the results of this method along with controls system should be mention. this system will help to develop the

SAGD and VAPX process and will reduce the heat loss and also, we can control the production rate of this method (Hascakir, 2018) {15}.

This article shows an overview of various design of FCD will discuss their process of regulation the fluid of the SAGD process, also has mentioned the weakness and strength of different system with various economic offering. Moreover, it shows how to use the present pressure loss model from FCDs. and apply this process in SAGD (Hascakir, 2018) {16}.

## Economic analysis of the SAGD and VAPEX methods

Nowadays, heavy oil attracts the world due to the significant amount of the heavy oil. But there are many challenges may face economic and operation while extracting heavy oil. newly, SAGD and VAPEX methods are used to enhance the production rate, these methods are economical (Moussa, 2018) {17}.

## Limitation and problems

There are several challenges and disadvantages with each method, such as steam cost, fresh water, and CO2 pollution these challenges from SAGD method, the VAPEX challenges is the production rate which may have low production rate (Moussa, 2018) {18}.

## Gap and Contribution to the body of knowledge relevant to the research problems

In this search has been learned about SAGD method, which consists of two wells, the bottom well is the production, and the other well is the injection well, it is above the production well by 5m. The steam is injected from the injection well to reduce the viscosity of the oil, the gravity assists the heated oil to move through production well. And also, it explains the VAPEX process as well, this process is sampler to the SAGD method, the difference is only the liquid that injects, in VAPEX it inject solvent or Benzene instead of hot water Moreover; the gap in this research was only the system and the components which will be used to inject these methods should mention with the cost of each component which will be used to extract the hydrocarbon by these methods (Moussa, 2018){19}.

It has been developed three models in this article, the purpose of creating a different model is to show and explained the economic revenue of each method SAGD and VAPEX methods in terms of NPV. the first model is the base which will do the sensitivity analysis and the study will carry out, to determine the optimum operation. the maximum NPVs which achieved by SAGD and VAPEX will compare with secondary recovery, will compare the Cumulative oil production (COP) and recovery factor, to know the performance of each methods SAGD and VAPEX process by using CMG simulator (Moussa, 2018){20}.

## Advantages and limitation in SAGD process

There are several advantages of utilizing steam drainage gravity (SAGD), in producing heavy oils, as compared with

another thermal method. Steam Drainage Gravity offers many of the methods financial and environmental helpful which made heavy oil in the industry more attractive and commercial. Moreover, the advantages of SAGD method show in Table 2.

SAGD process is used to increase the production rate of hydrocarbon from reservoir. There are several limitations of the SAGD method compared with VAPEX method those limitations are mention in Table 2.

Table 2: Advantages and disadvantages of SAGD technique

| Advantages of SAGD technique | Limitation of SAGD technique |
|---|---|
| 1. To reduce oil viscosity. <br> 2. Provide pressure to move the hydrocarbons into a production well <br> 3. It reduces $S_{orw}$ by steam distillation | 1. Not suitable in thin reservoirs <br> 2. Severe permeability damage due to clay swelling <br> 3. High capital need for steam generation <br> 4. Need to water treatment before disposal to the environment <br> 5. Impractical in offshore fields due to a limited area on the platform <br> 6. Higher cost of well completion, pump, cement, tubing, and casing at high temperature <br> 7. Too much heat loss into reservoirs containing an aquifer |

## Proper parameters to apply SAGD project

To make a good development plan to the reservoir, depending on the analyze, ability to gather and integrate the information from the geological data, reservoir, production as well as the economic.

The challenges which may face, have to know when and what level the integration should be done, not all EOR process can be applied, moreover, should analyze the oil properties and reservoir characteristics, and compare the data in screening criteria tables to select the suitable EOR methods which can be used to enhance oil recovery from the field (Siavashi, Garusi & Derakhshan, 2017) {21}.

Table 3: Screening criteria to select SAGD Method

| Reservoir data | Desirable value |
|---|---|
| Net Thickness | 35 ft or more |
| Depth | Less 4500 ft |
| Pressure | Around 150 psi |
| Permeability | 1000md or more |
| Vertical permeability | 100md or more |
| Oil viscosity | 2000cp or more |
| Transmissibility | 5 m.md/cp |
| Porosity | 20 % |

| Other positive characteristics | swelling clays & no gas cap require |
|---|---|

By using the Screening Parameters in table 3 and compare it with data of this reservoir to choose the method that is helpful which will get more production as well as the economic. Moreover; screening parameters show the

| Parameter | Desirable extent |
|---|---|
| Net Thickness | Less than 35 ft |
| Gas cap | May less than 20 m, also may economic |
| Reservoir permeability | >1 md |
| Rate of mobile oil | >500 bbl/acre-ft |

method that can be used for the field, based on the reservoir characteristics and oil properties, as the EOR method is costly and sensitive, so the data of the reservoir must analyze to select the best method of EOR (Majid, 2017) {22},

### Advantages and disadvantages of the VAPEX Process

VAPEX method is economically and invariantly process, moreover in this process there is no heat loss in under burden and overburden, so the operation at reservoir temperature, In-situ deasphalting, In-situ demetallizing, and heavy oil upgrading (the API gravity may decrease till 5 degrees).

Moreover, Vapor Extraction can be utilized as an alternative process to extract hydrocarbon and bitumen which is not applicable for thermal like the reservoir with High water saturation or Bottom water, Vertical fractures in reservoir, Less porosity, and Less thermal conductivity. In additional, there is some of the limitation may happen while applying the VAPEX method, the limitation and advantages are listed on the Table 4.

Table 4: Comparison between SAGD and VAPEX

| Advantages of the VAPEX Process | Disadvantages of the VAPEX method |
|---|---|
| 1. To reduce oil viscosity.<br>2. Provide pressure to move the hydrocarbons into a production well<br>3. It Reduce $S_{orw}$ by steam distillation<br>4. Low cost to generate this process<br>5. There is no heat loss<br>6. Suitable in thin reservoirs | 1. Operating Pressure<br>2. Non-Condensable Gas<br>3. Diffusivity of the Solvent<br>4. Consequences of Deasphalting<br>5. Solvent Injection Rate<br>6. Bottom Water<br>7. Gas Cap |

Generally, there are some of the items which make this process unique, furthermore this make the VAPEX more efficient than the thermal process, these items are no need energy consumption, is not harmful to the environment, very low pollution, in situ upgrading, and capital cost is low and etc.

### Proper parameters to apply VAPEX method

By using the Screening Parameters and compare it with data of the reservoir to choose the best method for the reservoir, so the secretin criteria are helpful to select the EOR method which use to increase the production as well as the economic. Moreover; the screening parameter is utilized for EOR method. Furthermore; screening criteria is used to select the applicable method. Thus; VAPEX screening criteria is mention below on the table 5, consequently screening parameters make the process economically (Soares, 2016) {23}.

Table 5: Screening criteria to select VAPEX Method (Siavashi, Garusi & Derakhshan, 2017) {24}.

### VAPEX advantages on the environment

Vapor extraction more friendly for the environment compared to the SAGD process. In additional VAPEX is considered as the no thermal method with less energy required, the VAPEX advantages on the environment are Roughly less than 93% of natural gas is needed in the VAPEX method compare with SAGD, and Around or less 93% of fresh water is utilized in VAPEX compare with the thermal method, this makes the case make it environmentally viable, this is because of decrease in using the H2 and decrease the emission of $CO_2$ and hence low of the gas pollution in the atmosphere.

### Sensitivity analysis.

The aim of VAPEX is to extract the heavy oil and remove bitumen from the domain, this will be accomplished by reducing the viscosity. when it enters the bitumen to butane the two miscible will react make liquid with less viscosity and permit bitumen to move while production, so the viscosity id the most important in modeling VAPEX method (Siavashi, Garusi & Derakhshan, 2017) {24}.

This type of study has been doing sensitivity analysis of VAPEX and SAGD methods for parameters which are well spacing, well length, and vertical separation.

In addition, for vertical separation, and well length is used single well to calculate the Net Present Value (NPV). Furthermore, for well spacing has been used, four wells to measure the spacing effect between wells. The effect of a vertical well in net present value was tested in different wells to know how the wells are affected by the production rate. At higher vertical separation, the net present value of SAGD method starts to decrease for each length, while in VAPEX process opposite is observed (Siavashi, Garusi & Derakhshan, 2017) {24}.

### Economic Advantages in VAPEX process

Vapor Extraction not only the alternative method for steam, but it is also an economic and environmentally process. Moreover; the cost of vapor extraction is attracting by utilizing simple facilities and process, very low costs to generate this method, there is no cost for steam generation and water process, and the VAPEX it uses a solvent which can be recycled and reuse to reduce the cost.

**Comparison between SAGD and VAPEX**

From all the research and dissection happen until now the enhancement of the SAGD method with maximum Recovery Factor (RF) 23%, and the net present value ($2×107) for 11 years. On the other hand, the vapor extraction has less recovery factor (RF) which is 18% with more NPV which is ($3.5×107) was obtained in this paper. Moreover; SAGD achieved more recovery factor and cumulative oil production and low NPV compare with VAPEX method, Vapor Extraction result's NPV 73% higher than SAGD. The higher NPV from VAPEX due to its low operation cost. Therefore, in SAGD method has higher RF, high environmental impact and less economic compared with VAPEX, in SAGD there is high of $CO_2$ emission which harms the environment (King Fahd University, 2018) {25}.

Table 6: Comparison between SAGD and VAPEX

| SAGD | VAPEX |
|---|---|
| Not suitable in thin reservoirs | Suitable in thin reservoirs |
| Severe permeability damage due to clay swelling | No clay swelling |
| High capital need for steam generation | No need to steam generation |
| Need to water treatment before disposal to environment | No water production |
| Higher cost of well completion, pump, cement, tubing, and casing at high temperature | Low-temperature operation |
| Too much heat loss into reservoirs containing an aquifer | Little or no heat loss to the overburden and under burden |

## V. METHODOLGY

In this project will use SAGD and VAPEX methods which help to increase the production rate, and also will prevent any errors that face the reservoir engineer during the production. also, will learn how to optimize the production by using the EOR method and using CMG simulator. The course of the research methodology applied in this project is depicted in Figure 6, as illustrated, there are six essential stages of processes that would be continuously worked on during the whole course of the project works. In each stage of the Enhance Oil Recovery (EOR) will simulate and modified through many scenarios in term of the injection patterns, production & injection wells' locations as well as the adjustment of different injection steam injection and solvent injection. By using the CMG simulator and construct the model of both model SAGD and VAPEX, then it will compare the results for each method, the more profitable and environmental will be selected as the best methods.
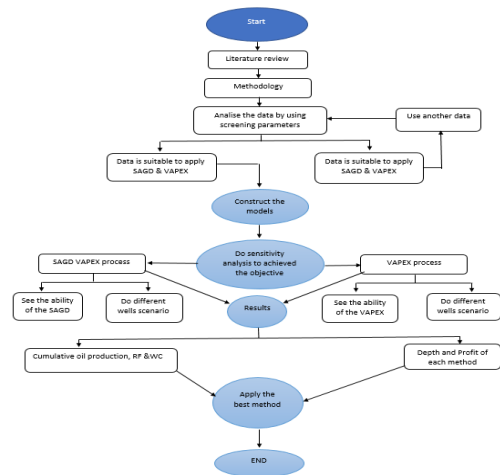


Figure 6: Project of research methodology.

Table 7: Objectives with Associated Methodologies.

| Objectives | Methodology |
|---|---|
| To construct SAGD method base in real data to evaluate Enhance Oil Recovery obtained from SAGD method. | For the first objective, CMG (STARTS) will be used to construct the model and find the optimum oil recovery. |
| To construct a VAPEX model to show a miscibility effect on Enhanced Oil Recovery (EOR). | For this objective, GMG (GEM) will be used to build the VAPEX method and show the miscibility effect. |
| To obtain optimum depth to switch from the SAGD method to the VAPEX method using sensitivity analysis from production outcome and the profit for different oil viscosity. | In this part will find the maximum depth for SAGD, and then will change to the VAPEX method, then discuss and analyze the results of each method with the cost, and see which methods has more profit. |
| To obtain best location of SAGD and VAPEX injection well locations. | For this objective, different scenarios of the SAGD method and VAPEX method will be created to get the best scenario with good profit to be selected. |

**SAGD process**

It shows in the Figure 7 show the SAGD methods process and what will do in this project, first of all, will be build the static model of the SAGD methods after that will be entering the PVT data of the real oil field which locating in Iran. Secondly will drills two wells one is the production wells and the other is the injection well, the injection well must be perforated to allow the hot water to change the viscosity of the oil. Finally, will run the model and show the results with a different scenario, furthermore will select the

best scenario which will give more recovery, this result will be compared with VAPEX method.
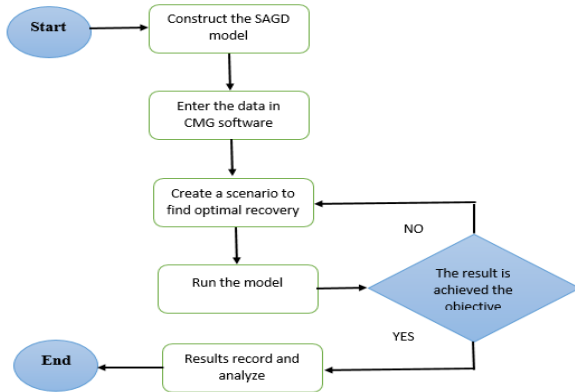


Figure 7: SAGD process

In this part of the simulation, it shows the SAGD process with two well, it also shows the change in pressure of the reservoir, so the Figure 8 show SAGD method. Moreover, in Table 8 show the volume in place.
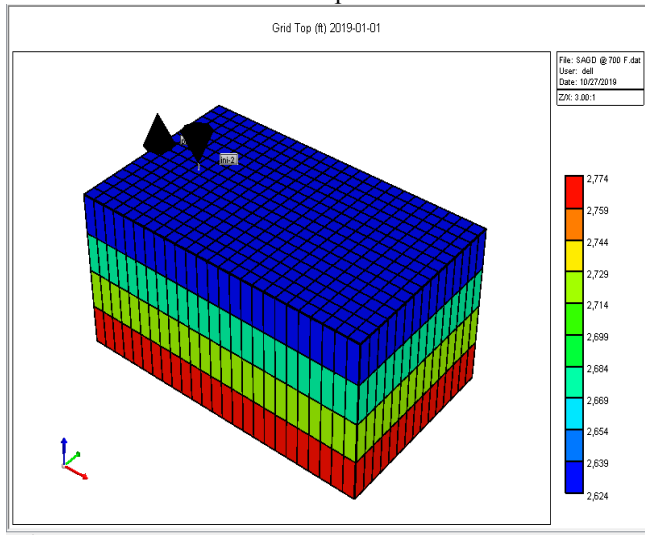


Figure 8: SAGD model

Table 8: Volume in place by SAGD model

| # | Item | units | value |
|---|------|-------|-------|
| 1 | Total Bulk Reservoir | RES FT3 | 1.87500E+08 |
| 2 | Total Pore Volume | RES FT3 | 3.57326E+07 |
| 3 | Total Hydrocarbon Po | RES FT3 | 3.21593E+07 |
| 4 | Original Oil in Place | STD BBL | 4.35161E+06 |
| 5 | Original Gas in Place | STD FT3 | 2.14433E+09 |

**VAPEX process**

It shows in the Figure 9 explain the VAPX method process and what will do in this project, first of all, will be build the static model of the VAPEX method after that will

be entering the PVT data of the real oil field which locating in Iran, the VAPEX model will be created in the GEM tool to its miscibility effect, this method is sampler to SAGD methods, however instead of injected steam will inject solvent

Secondly will drills two wells one is the production wells and the other is the injection well, the injection well must be perforated to allow the Benin to reduce the viscosity of the oil. finally, will run the model and show the results with a different scenario, furthermore will select the best scenario which will give more recovery, this result will be compared with the SAGD method.
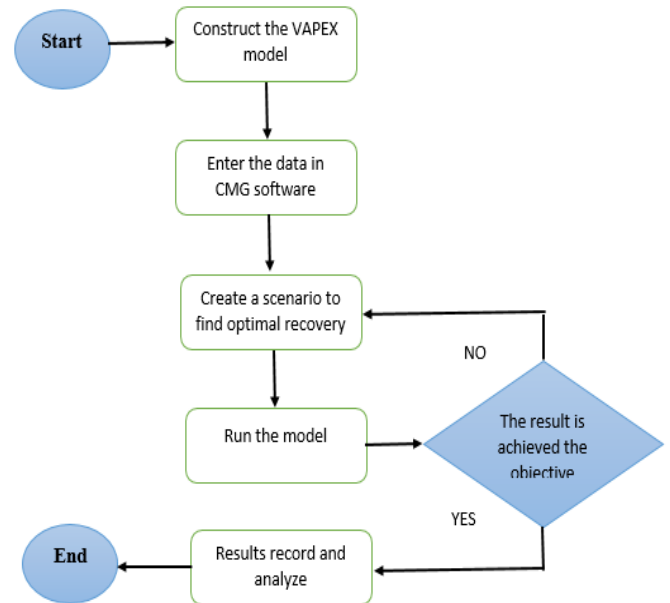


Figure 9: VAPEX process

In this part of the simulation, it shows the VAPEX process with two well, it also shows the change in pressure of the reservoir, so the Figure 10 show VAPEX method. Moreover, in Table 9 show the volume in place.
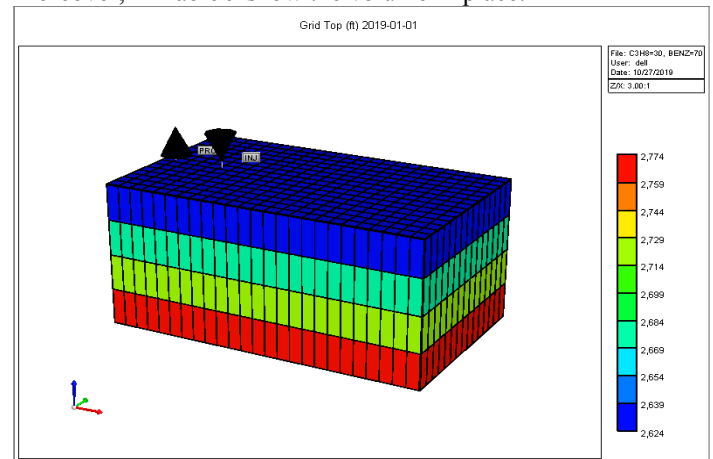


Figure 10: VAPEX model

Table 9: Volume in place by VAPEX model

| # | Item | units | value |
|---|------|-------|-------|
| 1 | Total Bulk Reservoir | RES FT3 | 1.87500E+08 |

| | | | |
|---|---|---|---|
| 2 | Total Pore Volume | RES FT3 | 3.57326E+07 |
| 3 | Total Hydrocarbon Po | RES FT3 | 3.21593E+07 |
| 4 | Original Oil in Place | STD BBL | 4.35161E+06 |
| 5 | Original Gas in Place | STD FT3 | 2.14433E+09 |

## RESERVOIR PARAMETERS FOR DEEP RESRVOIT

Based on real data will create the models for SAGD and VAPEX to be analyzed. Furthermore; will use this data in the CMG and Prosper software to overcome with the objectives of this project.

The Table 10 show the data for deep reservoir. Based on this data will create tow model of the SAGD and VAPEX then compered this result with both methods and considering the cost required to applies this method in deep reservoir.

Table 10 Data for Deep Reservoir

| Data | Values |
|---|---|
| Depth | 5500 ft |
| API | 13-15 |
| Type of the reservoir rock | Sandstone |
| Reservoir pressure | 3500 psi |
| Oil sulfur rang | 5% of weight |
| Oil saturation | 78% |
| Temperature | 140 ºF |
| Water saturation | 22% |
| Porosity | 19% |
| Permeability matric | 500md, 500md. 100md |
| Viscosity | 716.22cp |

Table 11 The reservoir dimensions

| The block number | 1500 |
|---|---|
| Dimension in x axis | 1250 (Ft) |
| Dimension in y axis | 750 (Ft) |
| Dimension in z axis | 200 (Ft) |

## VI. RESULTS AND ANALYSIS

### Wells location test

In this process will test the well location and spacing of the SAGD and VAPEX method, and based on this step will know the suitable distance between the production and the injection well, as well as the location of each well. Furthermore; will be chose the suitable distance and location of both methods in shallow and deep reservoir with considering the heat loss of the SAGD method.

The thermal injection and non-thermal injection are done by using the simulation STARS and GEM tools in CMG software. In this section will use both steps to create SAGD method by using SATRS which use for thermal model and it

is very efficient for this process, and will create the VAPEX method by using GEM tool which are used for compositional model, in this tool will show the miscibility effect of the VAPEX method.

In additional; will create two horizontal wells in parallel production well is set below the injection well for each method has the same process expect the materials that will inject inside the reservoir to reduce the viscosity.

Furthermore; will test the location with different distance and location then see the results for each test, the most recovery factor and cumulative oil production will consider as the suitable distance for this reservoir. Figure 11 & 12 show the models for SAGD and VAPEX methods with different well spacing between the production and injection wells.
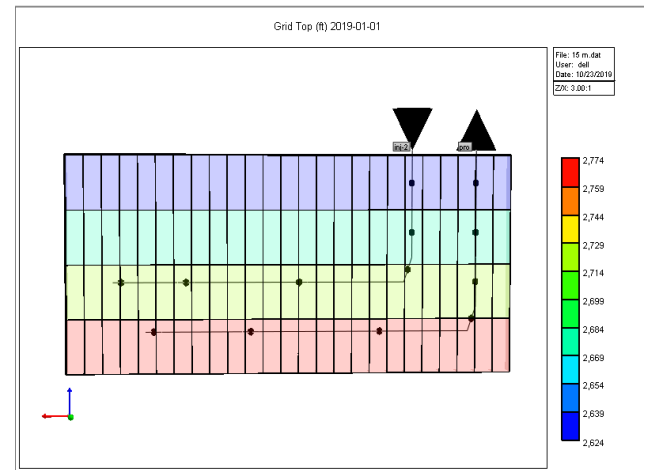


Figure 11: SAGD & VAPEX Model
at 15 m will spacing.
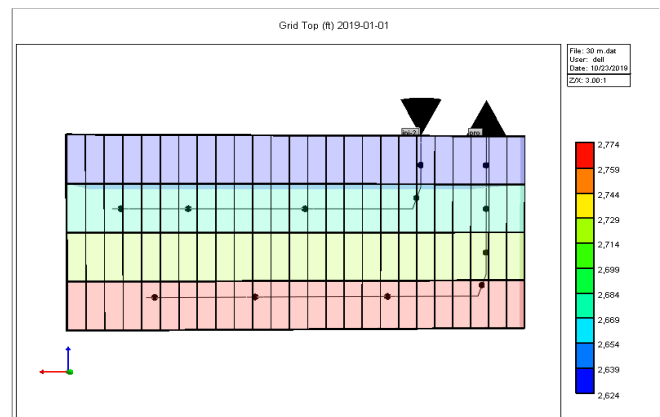


Figure 12: SAGD & VAPEX Model
at 15 m will spacing.

### Data collection for SAGD and VAPEX models

In this section will gather the results of both methods SAGD and VAPEX at different will spacing. Furthermore; the SAGD method has been injection the steam at 700 F for each location of injection wells, and at the VAPEX method has been injecting C3H8 with 30 % and BENZENE 70 % for each location of the injection wells, and based on these

results will see the applicable distance for SAGD and VAPEX which will be used in this project.

Table 12: Data collection for different will spacing

| Methods | SAGD method at Tinj = 700°F | | VAPEX method | |
|---|---|---|---|---|
| Distance | 15 m | 30 m | 15 m | 30 m |
| Reservoir Temperature | 140°F | 140°F | 140°F | 140°F |
| Material Balance error | 0.203% | 0.1266% | 0.0017% | 0.001% |
| Max change in pressure | -6.46psi | -9.18psi | -.637psi | -.666psi |
| Cumulative Oil production | 3.34e+6 bbl | 3.87e+6 bbl | 2.75e+6 bbl | 2.74e+6 bbl |
| RF | 60.4% | 69.8% | 62.1% | 62.03% |
| Production rate | 5000 bbl/d | 5000 bbl/d | 5000 bbl/d | 5000 bbl/d |
| WC | 64 % | 67.2 % | 0.024 % | 0.025 % |

## Data Analysis for SAGD and VAPEX models

Figure 13, shows the Recovery Factor (RF) of oil production for both method SAGD and VAPEX processes, and based on these results will select the suitable distance for the SAGD and VAPEX to be used in this project.

Furthermore, has been measures that method with different distance and this figure show the results of those methods with different distance between the production well and the injection well. In additional; the advantages of this graph show the ability of each method and which one has a higher recovery.

Moreover; in this section has been seen that the ability of the SAGD method change by changing the distance between the production well and the injection well, however, the VAPEX method remains the same or there is low change in the recovery factor.
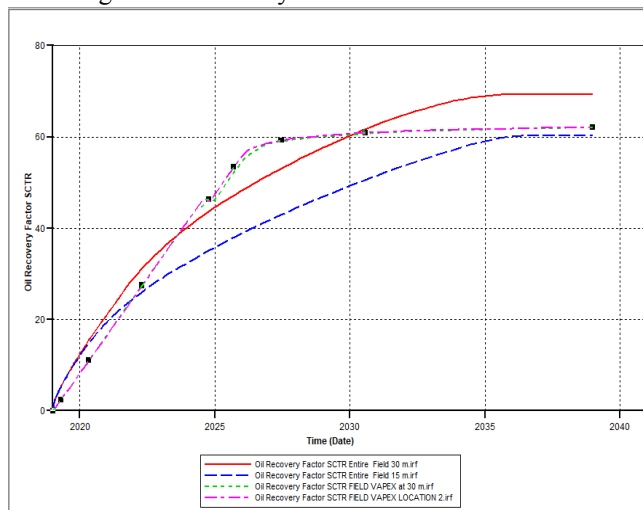


Figure 13: Results for SAGD & VAPEX Method at different well spacing.

## VII. CONCLUSION

The aim of this study is to design both methods by reservoir simulator and then to decide where to use each method. The outcome of this study is to choose a proper EOR method for specific reservoirs. The objectives of this study are:

The objectives of this study are:

1- To construct SAGD model based on the real data and find the best distance between injection and production wells when applying the SAGD method.

2- To construct a VAPEX model based on the real data and obtained the suitable distance between injection and production wells in VAPEX method

3- To analyze the results of SAGD and VAPEX methods in both reservoir shallow and deep based on real data

These objectives have been achieved by the tests which have been explained above. First of all, the first objectives have been achieved by creating the model of the SGAD method, in these objectives have been measured the ability of the SAGD method with different temperature and also it measured this process at different depth. Furthermore, it has been found that the ability of SAGD method at the shallow reservoir has higher than in a deep reservoir.

Second objectives have been achieved by creating the model in GEM tool, in this section has been used two processes to find the Minimum Miscibility Pressure (MMP) these processes are Slim Tube and WinPrope process, after finding the MMP and knowing that the miscibility effect of the VAPEX method at 3000psi by using both processes has been measured the ability of VAPEX method with different concentration of solvent. Moreover, has been test this process at different depth shallow and deep reservoir and the test has been done successfully, it has seen that the ability of VAPEX remains the same in a shallow and deep reservoir or there is a slight change in the recovery factor.

Finally, the last objectives which have been achieved by testing the ability of the SAGD and VAEPX method with different spacing between the production well and the injection well. Furthermore, it has been measured the spacing at 15 m spacing between the wells it was ok but there is low in recovery factor than in 30m, after testing the distance at 15m and 30m, it has been measured at 45m in this section has been faced errors in both methods SAGD and VAPEX, so it set the maximum spacing between those wells is 30m and the minimum spacing is 7m based on the thickness of the reservoir.

## VIII. LIMITATIONS

To begin with, there are certain limitations in this project that need to be emphasized. Firstly, creating the model properly with avoiding any errors which may affect the results of the simulation, these errors may come while selecting the PVT data in the component panel at SATRS or GEM.

The second, the Data limitations are difficult to solve than the numerical effects because the system start to modeled is inherently under-determined, so there is no enough information to make sure that the final result is accurate, thats why the simulation results must be compared with experimental results to see the results of each method and make sure this result is unique.

Finally, the limitation of this project was the actual field data, no data of actual filed was provided from the university or oil companies and it was so hard to find the data online which affect the outcomes of the project.

## IX. Recommendations and Suggestions for further research

Recommendations and Suggestions of the heavy oil projects, reduce the errors of the software which may face, by comparing the results of the simulation and experiments to be more accurate. For future work, the error will be reduced by developing the tools and the methodology in different ways and to certain limit.

The experimental results will be more practical and accurate in the future by finding actual filed data provided by Petroleum Company or official resources. In the future enhancement of the reservoir will be by using CMOST for running a sensitivity analysis. Recommendations and Suggestions of the heavy oil projects, reduce the errors of the software which may face, by comparing the results of the simulation and experiments to be more accurate. For future work, the error will be reduced by developing the tools and the methodology in different ways and to certain limit.

The experimental results will be more practical and accurate in the future by finding actual filed data provided by Petroleum Company or official resources. In the future enhancement of the reservoir will be by using CMOST for running a sensitivity analysis.

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# Low Resistivity Pay Identification in Carbonate Reservoirs of Yadavaran Oilfield

Mohammad Mardi

***Abstract***— Generally, the resistivity is high in oil layer and low in water layer. Yet there are intervals of oil-bearing zones showing low resistivity, high porosity, and low resistance. In the typical example, well A (depth: 4341.5-4372.0m), both Spectral Gamma Ray (SGR) and Corrected Gamma Ray (CGR) are relatively low; porosity varies from 12-22%. Above 4360 meters, the reservoir shows the conventional positive difference between deep and shallow resistivity with high resistance; below 4360m, the reservoir shows a negative difference with low resistance, especially at depths of 4362.4 meters and 4371 meters, deep resistivity is only $2\Omega.m$, and the CAST-V imaging map shows that there are low resistance substances contained in the pores or matrix in the reservoirs of this interval. The rock slice analysis data shows that the pyrite volume is 2-3% in the interval 4369.08m-4371.55m. A comprehensive analysis on the volume of shale (Vsh), porosity, invasion features of resistivity, mud logging, and mineral volume indicates that the possible causes for the negative difference between deep and shallow resistivities with relatively low resistance are erosional pores, caves, micritic texture and the presence of pyrite. Full-bore Drill Stem Test (DST) verified 4991.09 bbl/d in this interval. To identify and thoroughly characterize low resistivity intervals coring, Nuclear Magnetic Resonance (NMR) logging and further geological evaluation are needed.

***Keywords***— low resistivity pay, carbonates petrophysics, microporosity, porosity.

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# Experimental and Numerical Investigation on Delaminated Composite Plate

Dr Sreekanth T G, Kishorekumar S, Sowndhariya kumar J, Karthick R, Shanmugasuriyan S

***Abstract*—** Composites are increasingly being used in industries due to their unique properties such as high specific stiffness and specific strength, higher fatigue and wear resistances, and higher damage tolerance capability. Composites are prone to failures or damages that are difficult to identify, locate, and characterize due to their complex design features and complicated loading conditions. The lack of understanding of the damage mechanism of the composites leads to the uncertainties in the structural integrity and durability.

Delamination is one of the most critical failure mechanisms in laminated composites because it progressively affects the mechanical performance of fiber-reinforced polymer composite structures over time. The identification and severity characterization of delamination in engineering fields such as the aviation industry is critical for both safety and economic concerns. The presence of delamination alters the vibration properties of composites, such as natural frequencies, mode shapes, and so on. In this study, numerical analysis and experimental analysis were performed on delaminated and non-delaminated glass fiber reinforced polymer (GFRP) plate and the numerical and experimental analysis results were compared and error percentage has been found out.

**Keywords—** composites, delamination, natural frequency, mode shapes.

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# An Analysis of the Degree of Impatience of Decision Maker to Explain Anomalies of the Discounted Utility Model in Intertemporal Choices and to Improve Financial Advisors' Approach to Strategic Personalization

Roberta Martino, Viviana Ventre

***Abstract***— Most of the decision-making problems we face throughout our lives can be traced back to the typology of intertemporal choices, i.e., those choices whose consequences manifest only over time. The letter broad definition makes the subject particularly complex in two fundamental respects: the first one is that, deciding to get a result in the future necessarily implies renouncing to something in the present; the second aspect concerns the difficulty of keeping the coherence constant on future objectives. Intertemporal choices are studied from various perspectives, such as economics and psychology. The Discounted Utility Model is the reference for the study of intertemporal choice. This model assumes that the decision-making process of individuals is based on associating a level of utility to each alternative and then choosing the alternative with greater utility. The utility of the various prospects is strongly tied to the amplitude of the temporal interval that goes from the instant in which the choice is carried out and the moment in which the result is perceived. The discount rate encapsulates the impact that the indeterminacy of the future has on the decision-making process. The term anomalies indicate those empirical results that are difficult to rationalize compared to model predictions. Anomalies have become central for the search igniting criticisms based above all on the premise of a perfectly rational decision maker. The present work aims to analyse the degree of investors' impatience from a behavioural perspective by associating attitudes defined as non-rational with the analysis of inconsistency in intertemporal choices. The relationship between the preference reversal mechanism and the degree of decrease in impatience allows to review the anomalies of the discounted utility model because of human cognitive limitations. Specifically, inconsistency is described as the incongruence of an individual's decision-making process in choices involving perceivable short- or long- term outcomes. Since individuals are predictably irrational, it is necessary to diversify and personalize counselling strategies to improve the quality of their decisions according to the nudging technique. In this regard, the experimental phase ends with an application of Analytic Hierarchy Process model in the intertemporal choices. In this way, it is possible to indicate the weight of each anomaly regarding four investors' behavioural profiles. The idea is that there is no perfect solution but there is a better alternative for each subject. Therefore, consultants and automated devices that provide digital advice must consider the importance of the decision maker's personality to whom service is provided. Then it's necessary to nudge the individual toward a better option using the same cognitive boundaries.

***Keywords***— Behavioural anomalies, behavioural bias, impatience, intertemporal choice, personalized counselling.

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# Node Insertion in Coalescence Hidden-variable Fractal Interpolation Surface

Srijanani Anurag Prasad

*Abstract*—The Coalescence Hidden-variable Fractal Interpolation Surface (CHFIS) was built by combining interpolation data from the Iterated Function System (IFS). The interpolation data in a CHFIS comprises a row and/or column of uncertain values when a single point is entered. Alternatively, a row and/or column of additional points are placed in the given interpolation data to demonstrate the node added CHFIS. There are three techniques for inserting new points that correspond to the row and/or column of nodes inserted, and each method is further classified into four types based on the values of the inserted nodes. As a result, numerous forms of node insertion can be found in a CHFIS.

*Keywords*—Fractal, Interpolation, Iterated Function System, Coalescence, Node Insertion, Knot Insertion.

## I. Introduction

ONE of the most important contributions in understanding nature's structures is Benoit Mandelbrot's concept of fractals [1], [2]. The study of fractals soared to new heights with the invention of Barnsley's Fractal Interpolation Function (FIF) [3]. Massopust [4] extended this design to a triangular simplex surface, creating a Fractal Interpolation Surface (FIS) with co-planar interpolation points on the border. Then, Geronimo and Hardin [5], Xie, and Sun [6], Dalla [7], Malysz [8], and others created numerous FIS constructions on various sorts of domains that gave self-affine attractors.

Most naturally formed objects, such as rocks, sea surfaces, clouds, and so on, are made up of both self-affine and non-affine components. In [9], Chand and Kapoor created a non-diagonal Iterated Function System (IFS) that creates both self-affine and non-self-affine FIS simultaneously based on free and constrained variables on a large collection of interpolation data. Coalescence Hidden-variable Fractal Interpolation Surface was born from the attractor corresponding to such IFS (CHFIS). The smoothness, stability and fractal dimension of such a CHFIS was investigated in [10], [11] and [12].

Assume that interpolation data is obtained from various districts of a location and that one or more of the districts is later subdivided into smaller districts. In this scenario, we must employ node insertion to the preceding data to use it with smaller districts. Similarly, the results of some tests may provide us with a tip as to where we should place nodes while performing approximation. This leads to the investigation of the node insertion problem in bivariate functions.

Node insertion is described as the process of adding a new point to an existing set of interpolation data. The node insertion for Coalescence Hidden-variable Fractal Interpolation

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Functions (CHFIFs) was explored in [13]. If we introduce a single point in the bivariate situation, there are an unknown quantities in the row and/or column. As a result, the problem of new point inclusion in the Coalescence Hidden-variable Fractal Interpolation Surface is characterized by adding a row and/or column of new points. In the bivariate example, there are now several methods for inserting additional points. The impact of such new points on the related non-diagonal IFS and CHFIS is investigated in this work. Furthermore, the problem of node insertion is categorized into four types based on the values of inserted points for each method.

The organization of the paper is as follows: Section II provides an outline of how a CHFIS is constructed. Section III discusses the three possible methods for inserting new points into interpolation data. It is demonstrated that the new non-diagonal IFS produced utilizing the new set of interpolation data gives rise to a new CHFIS for each mode of node insertion. Following the study of the three techniques of insertion of new points, Section IV considers several types of insertion based on the values of added nodes for each approach. So, in the bivariate instance, there are 12 different types of node insertion. Finally, Section V provides an example of a computer model of a few different forms of insertion.

## II. Construction of CHFIS

A set of real parameters $\{t_{i,j}\}$ for $i = 0, 1, \ldots, N$ and $j = 0, 1, \ldots, M$ is introduced in a given interpolation data $\Lambda = \{(x_0, y_0, z_{0,0}), (x_1, y_0, z_{1,0}), \ldots, (x_0, y_1, z_{0,1}), \ldots, (x_N, y_M, z_{N,M})\}$ to form the generalized interpolation data $\Delta = \{(x_i, y_j, z_{i,j}, t_{i,j}) : i = 0, 1, \ldots, N \text{ and } j = 0, 1, \ldots, M\}$. From the interpolation data, the rectangle $S = I \times J = [x_0, x_N] \times [y_0, y_M]$ is subdivided into smaller rectangles $S_{n,m} = I_n \times J_m = [x_{n-1}, x_n] \times [y_{m-1}, y_m]$ for $n = 1, 2, \ldots, N$ and $m = 1, 2, \ldots, M$. For $n = 1, 2, \ldots, N$ and $m = 1, 2, \ldots, M$, the contractive homeomorphisms $L_n : I \to I_n, \tilde{L}_m : J \to J_m$ and the functions $F_{n,m} : S \times \mathbb{R}^2 \to D$, where $D$ is a compact subset of $\mathbb{R}^2$, are defined by:

$$L_n(x) = x_{n-1} + \frac{x_n - x_{n-1}}{x_N - x_0}\ (x - x_0),$$
$$\tilde{L}_m(y) = y_{m-1} + \frac{y_m - y_{m-1}}{y_M - y_0}\ (y - y_0) \tag{1}$$

and

$$F_{n,m}(x, y, z, t) = (\alpha_{n,m}\ z + \beta_{n,m}\ t + p_{n,m}(x, y),$$
$$\gamma_{n,m}\ t + q_{n,m}(x, y)). \tag{2}$$

In the above definition, $\alpha_{n,m}$ and $\gamma_{n,m}$ are called free variables and are chosen randomly but satisfying the condition:

$|\alpha_{n,m}| < 1$ and $|\gamma_{n,m}| < 1$. The value of $\beta_{n,m}$ are chosen such that $|\beta_{n,m}| + |\gamma_{n,m}| < 1$ and hence are called constrained variables. The functions $p_{n,m}$ and $q_{n,m}$ in $F_{n,m}$ are selected such that the following join-up conditions are satisfied:

$$F_{n,m}(x_0, y_0, z_{0,0}, t_{0,0}) = (z_{n-1,m-1}, t_{n-1,m-1})$$
$$F_{n,m}(x_N, y_0, z_{N,0}, t_{N,0}) = (z_{n,m-1}, t_{n,m-1})$$
$$F_{n,m}(x_0, y_M, z_{0,M}, t_{0,M}) = (z_{n-1,m}, t_{n-1,m})$$
$$F_{n,m}(x_N, y_M, z_{N,M}, t_{N,M}) = (z_{n,m}, t_{n,m}). \quad (3)$$

To ensure continuity, the functions $\tilde{F}_{n,m}$ are defined as:

$$\tilde{F}_{n,m}(x, y, z, t) = \begin{cases} F_{n+1,m}(x_0, y, z, t), & x = x_N, \\ & n = 1, \ldots, N-1, \\ & m = 1, \ldots, M \\ F_{n,m+1}(x, y_0, z, t), & y = y_M, \\ & n = 1, \ldots, N, \\ & m = 1, \ldots, M-1 \\ F_{n,m}(x, y, z, t), & \text{otherwise.} \end{cases}$$
$$(4)$$

It has been proved in [9] that if $\omega_{n,m}(x, y, z, t) = (L_n(x), \tilde{L}_m(y), \tilde{F}_{n,m}(x, y, z, t))$, the IFS defined by

$$\{S \times \mathbb{R}^2; \omega_{n,m}, n = 1, 2, \ldots N \text{ and } m = 1, 2, \ldots M\} \quad (5)$$

is hyperbolic with respect to a suitable metric equivalent to the Euclidean metric and there exists an attractor $G \subseteq \mathbb{R}^4$ satisfying $G = \bigcup_{n=1}^{N} \bigcup_{m=1}^{N} \omega_{n,m}(G)$ and $G$ is graph of a continuous function $f : S \to \mathbb{R}^2$ such that $f(x_i, y_j) = (z_{i,j}, t_{i,j})$ for $i = 0, 1, \ldots, N$ and $j = 0, 1, \ldots, M$. Hence the Coalescence Hidden variable Fractal Interpolation Surface (CHFIS) is defined as

*Definition 1:* The **Coalescence Hidden variable Fractal Interpolation Surface (CHFIS)** for the given interpolation data $\{(x_i, y_j, z_{i,j}) : i, j = 0, 1, \ldots, N\}$ is defined as the graph of projection $f_1$ of $f$ on $\mathbb{R}^3$, where $f_1$ is the first component of the function $f = (f_1, f_2)$.

*Remark 1:* The function $f_1$ is called a Coalescence Hidden-variable Fractal Interpolation bivariate function as it exhibits both self-affine and non-self-affine nature. For the same interpolation data, the function $f_2(x, y)$ is a self-affine bivariate function.

## III. METHODS OF INSERTION OF NEW POINTS

**T**HE problem of node insertion in the bivariate situation is characterized by introducing a row and/or column of additional points. In order to enter additional points, there are three options.

**Method 1**: The first method is inserting a point $\hat{x}$ between $x_{k-1}$ and $x_k$. This gives a column of new points as $\Gamma_1 = \{(\hat{x}, y_0, \hat{z}_{*,0}, \hat{t}_{*,0}), \ldots, (\hat{x}, y_M, \hat{z}_{*,M}, \hat{t}_{*,M})\}$ in the generalized interpolation data $\Delta$. So, the new generalized interpolation data is
$$\widehat{\Delta}_1 = \Big\{ (x_0, y_0, z_{0,0}, t_{0,0}), \ldots, (x_{k-1}, y_0, z_{k-1,0}, t_{k-1,0}),$$

$$(\hat{x}, y_0, \hat{z}_{*,0}, \hat{t}_{*,0}), (x_k, y_0, z_{k,0}, t_{k,0}), \ldots \ldots,$$
$$(x_N, y_0, z_{N,0}, t_{N,0}), \ldots, (x_0, y_M, z_{0,M}, t_{0,M}), \ldots,$$
$$(x_{k-1}, y_M, z_{k-1,M}, t_{k-1,M}), (\hat{x}, y_M, \hat{z}_{*,M}, \hat{t}_{*,M}),$$
$$(x_k, y_M, z_{k,M}, t_{k,M}), \ldots, (x_N, y_M, z_{N,M}, t_{N,M}) \Big\}. \text{ The interval } I_k \text{ is split into two intervals } I_k^l = [x_{k-1}, \hat{x}] \text{ and } I_k^r = [\hat{x}, x_k] \text{ which in turn gives that the rectangles } S_{k,m}, m = 1, 2, \ldots, M, m \neq l \text{ are broken into two rectangles, say } S_{k,m}^l = I_k^l \times J_m \text{ and } S_{k,m}^r = I_k^r \times J_m. \text{ Define } L_k^l : I \to I_k^l \text{ and } L_k^r : I \to I_k^r \text{ as}$$

$$L_k^l(x) = x_{k-1} + \frac{\hat{x} - x_{k-1}}{x_N - x_0} (x - x_0)$$
$$L_k^r(x) = \hat{x} + \frac{x_k - \hat{x}}{x_N - x_0} (x - x_0) \quad (6)$$

For $m = 1, 2, \ldots, M$, define $F_{k,m}^l : S \to S_{k,m}^l$ and $F_{k,m}^r : S \to S_{k,m}^r$ as

$$F_{k,m}^l(x, y) = (\alpha_{k,m}^l z + \beta_{k,m}^l t + p_{k,m}^l(x, y),$$
$$\gamma_{k,m}^l t + q_{k,m}^l(x, y)), \ m = 1, 2, \ldots, M$$
$$F_{k,m}^r(x, y) = (\alpha_{k,m}^r z + \beta_{k,m}^r t + p_{k,m}^r(x, y),$$
$$\gamma_{k,m}^r t + q_{k,m}^r(x, y)), \ m = 1, 2, \ldots, M \quad (7)$$

where, $\alpha_{k,m}^l, \alpha_{k,m}^r, \gamma_{k,m}^l, \gamma_{k,m}^r$ are free variables whose absolute value is strictly less than one; $\beta_{k,m}^l$ and $\beta_{k,m}^r$ are constrained variables such that $|\beta_{k,m}^l| + |\gamma_{k,m}^l| < 1$ and $|\beta_{k,m}^r| + |\gamma_{k,m}^r| < 1$. The functions $p_{k,m}^l, p_{k,m}^r, q_{k,m}^l$ and $q_{k,m}^r$ are continuous functions selected such that the functions $F_{k,m}^l$ map the end points of the rectangle $S$ to end points of the rectangle $S_{k,m}^l$ and $F_{k,m}^r$ map the end points of the rectangle $S$ to end points of the rectangle $S_{k,m}^r$ i.e. $F_{k,m}^l$ and $F_{k,m}^r$ for $m = 1, \ldots, M$ satisfy the following conditions:

$$F_{k,m}^l(x_0, y_0, z_{0,0}, t_{0,0}) = (z_{k-1,m-1}, t_{k-1,m-1})$$
$$F_{k,m}^r(x_0, y_0, z_{0,0}, t_{0,0}) = (\hat{z}_{*,m-1}, \hat{t}_{*,m-1})$$
$$F_{k,m}^l(x_0, y_M, z_{0,M}, t_{0,M}) = (z_{k-1,m}, t_{k-1,m})$$
$$F_{k,m}^r(x_0, y_M, z_{0,M}, t_{0,M}) = (\hat{z}_{*,m}, \hat{t}_{*,m})$$
$$F_{k,m}^l(x_N, y_0, z_{N,0}, t_{N,0}) = (\hat{z}_{*,m-1}, \hat{t}_{*,m-1})$$
$$F_{k,m}^r(x_N, y_0, z_{N,0}, t_{N,0}) = (z_{k,m-1}, t_{k,m-1})$$
$$F_{k,m}^l(x_N, y_M, z_{N,M}, t_{N,M}) = (\hat{z}_{*,m}, \hat{t}_{*,m})$$
$$F_{k,m}^r(x_N, y_M, z_{N,M}, t_{N,M}) = (z_{k,m}, t_{k,m})$$

*Theorem 1:* Let $\widehat{\Delta}_1 = \Delta \bigcup \Gamma_1$. Then,

$$\Big\{ S \times \mathbb{R}^2; \omega_{n,m}, \ n = 1, \ldots, N, n \neq k;$$
$$\omega_{k,m}^l \ \omega_{k,m}^r, \ m = 1, \ldots, M \Big\} \quad (8)$$

with $\omega_{k,m}^l = (L_k^l, \tilde{L}_m, F_{k,m}^l)$ and
$\omega_{k,m}^r = (L_k^r, \tilde{L}_m, F_{k,m}^r)$ is a hyperbolic IFS on
$S \times \mathbb{R}^2$ and there exists an attractor $\hat{A}$ that satisfies
$\hat{A} = \bigcup_{\substack{n=1 \\ n \neq k}}^{N} \bigcup_{m=1}^{M} \omega_{n,m}(\hat{A}) \bigcup_{m=1}^{M} \bigcup_{p \in \{l,r\}} \omega_{k,m}^p(\hat{A})$. In addition, the aforementioned IFS's attractor is a graph of a continuous bivariate function that passes over the new generalized interpolation points $\widehat{\Delta}_1$.

*Proof:* Suppose $\alpha_{k,m}^p \leq \alpha_{k,m}$, $\gamma_{k,m}^p \leq \gamma_{k,m}$ and $\beta_{k,m}^p \leq \beta_{k,m}$ for all $m = 1, 2, \ldots, M$ and $p \in \{l, r\}$. Then the maps $\omega_{k,m}^l$ and $\omega_{k,m}^r$ are contraction maps for the same metric, by which $\omega_{n,m}$ are contraction maps. Alternatively, a metric could be defined as in [9] where, $\omega_{n,m}; n = 1, 2, \ldots N, n \neq k$, $\omega_{k,m}^l; \omega_{k,m}^r; m = 1, 2, \ldots, M$, are contraction maps. Then the IFS represented by (8) is hyperbolic and contains an attractor $\hat{A}$ that fulfills

$$\hat{A} = \bigcup_{\substack{n=1 \\ n \neq k}}^N \bigcup_{m=1}^M \omega_{n,m}(\hat{A}) \bigcup_{m=1}^M \omega_{k,m}^l(\hat{A}) \bigcup_{m=1}^M \omega_{k,m}^r(\hat{A}).$$

Consider the metric space of functions $(\mathcal{G}, d_\mathcal{G})$ such that $\mathcal{G} = \Big\{ g \mid g : S \to \mathbb{R}^2$ is continuous,

$g(x_0, y_0) = (z_{0,0}, t_{0,0})$, $g(x_N, y_0) = (z_{N,0}, t_{N,0})$,

$g(x_0, y_M) = (z_{0,M}, t_{0,M})$, and $g(x_N, y_M) = (z_{N,M}, t_{N,M}) \Big\}$

and $d_\mathcal{G}(g, \hat{g}) = \max\limits_{(x,y) \in S} \Big( |g_1(x,y) - \hat{g}_1(x,y)|, |g_2(x,y) - \hat{g}_2(x,y)| \Big)$, for $g, \hat{g} \in \mathcal{G}$. Define Read-Bajraktarević operator on $(\mathcal{G}, d_\mathcal{G})$ as

$$\hat{T}(g)(x,y) = F_{n,m}(L_n^{-1}(x), \tilde{L}_m^{-1}(y), g(L_n^{-1}(x), \tilde{L}_m^{-1}(y))),$$
$$(x,y) \in S_{n,m}, n = 1, 2, \ldots, N; n \neq k,$$
$$\hat{T}(g)(x,y) = F_{k,m}^l(L_k^{l^{-1}}(x), \tilde{L}_m^{-1}(y), g(L_k^{l^{-1}}(x), \tilde{L}_m^{-1}(y))),$$
$$(x,y) \in S_{k,m}^l,$$
$$\hat{T}(g)(x,y) = F_{k,m}^r(L_k^{r^{-1}}(x), \tilde{L}_m^{-1}(y), g(L_k^{r^{-1}}(x), \tilde{L}_m^{-1}(y))),$$
$$(x,y) \in S_{k,m}^r \qquad (9)$$

for all $m = 1, 2, \ldots, M$. Following the lines of proof as in [9], it is straightforward to demonstrate that the bivariate Read-Bajraktarević operator defined by (9) is a contraction map and that a continuous bivariate function $\hat{f} : S \to \mathbb{R}^2$ exists which passes through the generalized interpolation points $\widehat{\Delta}_1$. In addition, distinctiveness provides $\hat{A}$ represents the graph of the function $\hat{f}$. ∎

**Method 2**: The second method is inserting a point $\hat{y}$ between $y_{l-1}$ and $y_l$ which gives a row of new points as $\Gamma_2 = \{(x_0, \hat{y}, \hat{z}_{0,*}, \hat{t}_{0,*}), (x_1, \hat{y}, \hat{z}_{1,*}, \hat{t}_{1,*}), \ldots\ldots, (x_N, \hat{y}, \hat{z}_{N,*}, \hat{t}_{N,*})\}$ in the generalized interpolation data $\Delta$. Here, the new generalized interpolation data is $\widehat{\Delta}_2 =$
$\Big\{ (x_0, y_0, z_{0,0}, t_{0,0}), \ldots\ldots, (x_N, y_0, z_{N,0}, t_{N,0}), \ldots\ldots,$
$(x_0, y_{l-1}, z_{0,l-1}, t_{0,l-1}), \ldots\ldots, (x_N, y_{l-1}, z_{N,l-1}, t_{N,l-1}),$
$(x_0, \hat{y}, \hat{z}_{0,*}, \hat{t}_{0,*}), \ldots\ldots, (x_N, \hat{y}, \hat{z}_{N,*}, \hat{t}_{N,*}), (x_0, y_l, z_{0,l}, t_{0,l}),$
$\ldots\ldots, (x_N, y_l, z_{N,l}, t_{N,l}), \ldots\ldots, (x_0, y_M, z_{0,M}, t_{0,M}), \ldots,$
$(x_N, y_M, z_{N,M}, t_{N,M}) \Big\}$. The interval $J_l$ is broken into two intervals $J_l^b = [y_{l-1}, \hat{y}]$ and $J_l^t = [\hat{y}, y_l]$ and the rectangles $S_{n,l}$ for $n = 1, 2, \ldots, N$ are split into two rectangles, say $S_{n,l}^b = I_n \times J_l^b$ and $S_{n,l}^t = I_n \times J_l^t$.

Define $\tilde{L}_l^b : J \to J_l^b$ and $\tilde{L}_l^t : J \to J_l^t$ are defined as

$$\tilde{L}_l^b(y) = y_{l-1} + \frac{\hat{y} - y_{l-1}}{y_M - y_0}(y - y_0)$$

$$\tilde{L}_l^t(y) = \hat{y} + \frac{y_l - \hat{y}}{y_M - y_0}(y - y_0) \qquad (10)$$

For $n = 1, 2, \ldots, N$, define $F_{n,l}^b : S \to S_{n,l}^b$ and

$F_{n,l}^t : S \to S_{n,l}^t$ as

$$F_{n,l}^b(x,y) = \big( \alpha_{n,l}^b z + \beta_{n,l}^b t + p_{n,l}^b(x,y), \\ \gamma_{n,l}^b t + q_{n,l}^b(x,y) \big),$$
$$n = 1, 2, \ldots, N, \ n \neq k$$
$$F_{n,l}^t(x,y) = \big( \alpha_{n,l}^t z + \beta_{n,l}^t t + p_{n,l}^t(x,y), \\ \gamma_{n,l}^t t + q_{n,l}^t(x,y) \big),$$
$$n = 1, 2, \ldots, N, \ n \neq k \qquad (11)$$

where, $\alpha_{n,l}^b, \alpha_{n,l}^t, \gamma_{n,l}^b, \gamma_{n,l}^t$ are free variables whose absolute value is strictly less than one; $\beta_{n,l}^b$ and $\beta_{n,l}^t$ are constrained variables such that $|\beta_{n,l}^b| + |\gamma_{n,l}^b| < 1$ and $|\beta_{n,l}^t| + |\gamma_{n,l}^t| < 1$. The functions $p_{n,l}^b, p_{n,l}^t, q_{n,l}^b$ and $q_{n,l}^t$ are continuous functions selected such that the functions $F_{n,l}^b$ map the end points of the rectangle $S$ to end points of the rectangle $S_{n,l}^b$ and $F_{n,l}^t$ map the end points of the rectangle $S$ to end points of the rectangle $S_{n,l}^t$ i.e. $F_{n,l}^b$ and $F_{n,l}^b$ for $n = 1, \ldots, N$ satisfy the following conditions:

$$F_{n,l}^b(x_0, y_0, z_{0,0}, t_{0,0}) = (z_{n-1, l-1}, t_{n-1, l-1})$$
$$F_{n,l}^t(x_0, y_0, z_{0,0}, t_{0,0}) = (\hat{z}_{n-1,*}, \hat{t}_{n-1,*})$$
$$F_{n,l}^b(x_0, y_M, z_{0,M}, t_{0,M}) = (\hat{z}_{n-1,*}, \hat{t}_{n-1,*})$$
$$F_{n,l}^t(x_0, y_M, z_{0,M}, t_{0,M}) = (z_{n-1,l}, t_{n-1,l})$$
$$F_{n,l}^b(x_N, y_0, z_{N,0}, t_{N,0}) = (z_{n,l-1}, t_{n,l-1})$$
$$F_{n,l}^t(x_N, y_0, z_{N,0}, t_{N,0}) = (\hat{z}_{n,*}, \hat{t}_{n,*})$$
$$F_{n,l}^b(x_N, y_M, z_{N,M}, t_{N,M}) = (\hat{z}_{n,*}, \hat{t}_{n,*})$$
$$F_{n,l}^t(x_N, y_M, z_{N,M}, t_{N,M}) = (z_{n,l}, t_{n,l})$$

*Theorem 2:* Let $\widehat{\Delta}_2 = \Delta \bigcup \Gamma_2$. Then,

$$\left\{ \begin{array}{l} S \times \mathbb{R}^2; \omega_{n,m}; \ m = 1, \ldots, M, m \neq l, \\ \\ \omega_{n,l}^b; \ \omega_{n,l}^t; \ n = 1, \ldots, N, \end{array} \right\} \qquad (12)$$

with $\omega_{n,l}^b = (L_n, \tilde{L}_l^b, F_{n,l}^b)$ and $\omega_{n,l}^t = (L_n, \tilde{L}_l^t, F_{n,l}^t)$ is a hyperbolic IFS on $S \times \mathbb{R}^2$ and there exists an attractor $\hat{A}$ that satisfies $\hat{A} = \bigcup\limits_{\substack{m=1 \\ m \neq l}}^M \bigcup\limits_{n=1}^N \omega_{n,m}(\hat{A}) \bigcup\limits_{n=1}^N \bigcup\limits_{q \in \{b,t\}} \omega_{n,l}^q(\hat{A})$. Furthermore, the attractor of the aforementioned IFS is a graph of a continuous bivariate function that passes through the new generalized interpolation points. $\widehat{\Delta}_2$.

*Proof:* Suppose $\alpha_{n,l}^q \leq \alpha_{n,l}$, $\gamma_{n,l}^q \leq \gamma_{n,l}$ and $\beta_{n,l}^q \leq \beta_{n,l}$ for all $m = 1, 2, \ldots, M$ and $q \in \{b, t\}$. Then the maps $\omega_{n,l}^b$ and $\omega_{n,l}^t$ are contraction maps for the same metric by which $\omega_{n,m}$ are contraction maps. Or else, a metric could be defined as in [9] where, $\omega_{n,m}; m = 1, \ldots, M, m \neq l, \omega_{n,l}^b; \omega_{n,l}^t; \ n = 1, 2, \ldots N$ are contraction maps. Then, the IFS given by (12) is hyperbolic and contains an attractor $\hat{A}$ which fulfills $\hat{A} = \bigcup\limits_{\substack{m=1 \\ m \neq l}}^N \bigcup\limits_{n=1}^N \omega_{n,m}(\hat{A}) \bigcup\limits_{n=1}^N \omega_{n,l}^b(\hat{A}) \bigcup\limits_{n=1}^N \omega_{n,l}^t(\hat{A})$.

Consider the metric space of continuous functions $(\mathcal{G}, d_\mathcal{G})$

and define Read-Bajraktarević operator on $(\mathcal{G}, d_\mathcal{G})$ as

$$
\begin{aligned}
&\hat{T}(g)(x,y) \\
&= F_{n,m}(L_n^{-1}(x), \tilde{L}_m^{-1}(y), g(L_n^{-1}(x), \tilde{L}_m^{-1}(y))), \\
&\quad \text{for } (x,y) \in S_{n,m}, m = 1, 2, \ldots, M; m \neq l \\
&\hat{T}(g)(x,y) \\
&= F_{n,l}^b(L_n^{-1}(x), \tilde{L}_l^{b^{-1}}(y), g(L_n^{-1}(x), \tilde{L}_l^{b^{-1}}(y))), \\
&\quad \text{for } (x,y) \in S_{n,l}^b \\
&\hat{T}(g)(x,y) \\
&= F_{n,l}^t(L_n^{-1}(x), \tilde{L}_l^{t^{-1}}(y), g(L_n^{-1}(x), \tilde{L}_l^{t^{-1}}(y))), \\
&\quad \text{for } (x,y) \in S_{n,l}^t
\end{aligned}
\tag{13}
$$

for $n = 1, 2, \ldots, N$. Just as in case (i), the bivariate Read-Bajraktarević operator defined by (13) is a contraction map and there exists a continuous bivariate function $\hat{f} : S \to \mathbb{R}^2$ which passes through the new generalized interpolation points $\widehat{\Delta}_2$. Additionally, uniqueness indicates that $\hat{A}$ is graph of the function $\hat{f}$. ∎

**Method 3**: The third kind is inserting the point $(\hat{x}, \hat{y})$ in the given interpolation data where, $x_{k-1} < \hat{x} < x_k$ and $y_{l-1} < \hat{y} < y_l$. Here, a row and a column of new points given by $\Gamma = \{(\hat{x}, y_0, \hat{z}_{*,0}, \hat{t}_{*,0}), \ldots, (\hat{x}, y_M, \hat{z}_{*,M}, \hat{t}_{*,M}), (x_0, \hat{y}, \hat{z}_{0,*}, \hat{t}_{0,*}), \ldots, (x_N, \hat{y}, \hat{z}_{N,*}, \hat{t}_{N,*}), (\hat{x}, \hat{y}, \hat{z}, \hat{t})\}$ is inserted in the generalized interpolation data $\Delta$. It is easy to see that the third case is nothing but combination of Method 1 and Method 2.

*Theorem 3:* Let $\widehat{\Delta} = \Delta \bigcup \Gamma$. Then,

$$
\begin{aligned}
\Big\{ &S \times \mathbb{R}^2; \ \omega_{n,m}, \ n = 1, \ldots, N, \ m = 1, \ldots, M, \ n \neq k, \ m \neq l; \\
&\omega_{n,l}^p, n = 1, \ldots, N, \ p \in \{b,t\}, n \neq k; \\
&\omega_{k,m}^A \ m = 1, \ldots, M, m \neq l, p \in \{l,r\}; \\
&\omega_{k,l}^p, p \in \{(l,b), (r,b), (l,t), (r,t)\} \Big\}
\end{aligned}
\tag{14}
$$

with $\omega_{n,m}^p = (L_n^p, \tilde{L}_m^p, F_{n,m}^p)$ is a hyperbolic IFS on $S \times \mathbb{R}^2$ and there exists an attractor $\hat{A}$ that satisfies

$$
\hat{A} = \left( \bigcup_{\substack{n=1 \\ n \neq k}}^N \bigcup_{\substack{m=1 \\ m \neq l}}^M \omega_{n,m}(\hat{A}) \bigcup_{\substack{n=1 \\ n \neq k}}^N \bigcup_{p \in \{b,t\}} \omega_{n,l}^p(\hat{A}) \right. \\
\left. \bigcup_{\substack{m=1 \\ m \neq l}}^M \bigcup_{p \in \{l,r\}} \omega_{k,m}^p(\hat{A}) \bigcup_{p \in \{(l,b),(r,b),(l,t),(r,t)\}} \omega_{k,l}^p(\hat{A}) \right).
$$

In addition, the attractor of the aforementioned IFS is graph of a continuous bivariate function that passes across the generalized interpolation points $\widehat{\Delta}$.

*Proof:* Let $\Gamma_1 = \{(\hat{x}, y_0, \hat{z}_{*,0}, \hat{t}_{*,0}), \ldots, (\hat{x}, y_M, \hat{z}_{*,M}, \hat{t}_{*,M})\}$ and $\Gamma_3 = \{(x_0, \hat{y}, \hat{z}_{0,*}, \hat{t}_{0,*}), \ldots, (\hat{x}, \hat{y}, \hat{z}, \hat{t}), \ldots (x_N, \hat{y}, \hat{z}_{N,*}, \hat{t}_{N,*})\} = \Gamma_2 \bigcup (\hat{x}, \hat{y}, \hat{z}, \hat{t})$. Then, Theorem 1 is applied on $\widehat{\Delta}_1 = \Delta \bigcup \Gamma_1$ followed by Theorem 2 on $\widehat{\Delta} = \widehat{\Delta}_1 \bigcup \Gamma_3$. So, there exist a continuous bivariate function $\hat{f} : S \to \mathbb{R}^2$ passing through the new generalized interpolation points $\widehat{\Delta}$. ∎

*Remark 2:* In the above Theorem 3, suppose $\Gamma_2 = \{(x_0, \hat{y}, \hat{z}_{0,*}, \hat{t}_{0,*}), \ldots, (x_N, \hat{y}, \hat{z}_{N,*}, \hat{t}_{N,*})\}$ and $\Gamma_3 = \{(\hat{x}, y_0, \hat{z}_{*,0}, \hat{t}_{*,0}), \ldots, (\hat{x}, \hat{y}, \hat{z}, \hat{t}) \ldots (\hat{x}, y_M, \hat{z}_{*,M}, \hat{t}_{*,M})\} = \Gamma_1 \bigcup (\hat{x}, \hat{y}, \hat{z}, \hat{t})$. In this case, Theorem 2 is applied first on $\widehat{\Delta}_2 = \Delta \bigcup \Gamma_2$ followed by Theorem 1 on $\widehat{\Delta} = \widehat{\Delta}_2 \bigcup \Gamma_3$. Again, it is obtained that there exist a continuous function $\hat{f} : S \to \mathbb{R}^2$ passing through the new generalized interpolation points $\widehat{\Delta}$.

## IV. Different kinds of node insertion

LET us now describe different types of insertion according to the values of inserted nodes for each method of insertion. Suppose $\hat{f} = (\hat{f}_1, \hat{f}_2)$ is a component-wise expression of the function $\hat{f}$. The graph of $\hat{f}_1$ then becomes a CHFIS that passes through the interpolation data $\widehat{\Lambda}$.

**Method 1**: In this method, a column of new points are inserted in the given interpolation data.

- If $\hat{t}_{*,m} = f_2(\hat{x}, y_m)$ for all $m = 0, 1, \ldots, M$ and $\hat{t} = f_2(\hat{x}, \hat{y})$ but $\hat{z}_{*,m} \neq f_1(\hat{x}, y_m)$ for some $m = 1, 2, \ldots, M$ or $\hat{z} \neq f_1(\hat{x}, \hat{y})$ then it is called **C-Node-Knot** insertion problem.
- If $\hat{z}_{*,m} = f_1(\hat{x}, y_m)$ for all $m = 0, 1, \ldots, M$ and $\hat{z} = f_1(\hat{x}, \hat{y})$ but $\hat{t}_{*,m} \neq f_2(\hat{x}, y_m)$ for some $m = 1, 2, \ldots, M$ or $\hat{t} \neq f_2(\hat{x}, \hat{y})$ then it is called **C-Knot-Node** insertion problem.
- If $\hat{z}_{*,m} = f_1(\hat{x}, y_m)$, $\hat{t}_{*,m} = f_2(\hat{x}, y_m)$ for all $m = 0, 1, \ldots, M$, $\hat{z} = f_1(\hat{x}, \hat{y})$ and $\hat{t} = f_2(\hat{x}, \hat{y})$ then it is called **C-Knot-Knot** insertion problem.
- If $\hat{z}_{*,m} \neq f_1(\hat{x}, y_m)$ and $\hat{t}_{*,m} \neq f_2(\hat{x}, y_m)$ for some $m = 0, 1, \ldots, M$ then it is called **C-Node-Node** insertion problem.

**Method 2**: In this method, a row of new points are inserted in the given interpolation data.

- If $\hat{t}_{n,*} = f_2(x_n, \hat{y})$ for all $n = 0, 1, \ldots, N$ and $\hat{t} = f_2(\hat{x}, \hat{y})$ but $\hat{z}_{n,*} \neq f_1(x_n, \hat{y})$ for some $n = 1, 2, \ldots, N$ or $\hat{z} \neq f_1(\hat{x}, \hat{y})$ then it is called **R-Node-Knot** insertion problem.
- If $\hat{z}_{n,*} = f_1(x_n, \hat{y})$ for all $n = 0, 1, \ldots, N$ and $\hat{z} = f_1(\hat{x}, \hat{y})$ but $\hat{t}_{n,*} \neq f_2(x_n, \hat{y})$ for some $n = 1, 2, \ldots, N$ or $\hat{t} \neq f_2(\hat{x}, \hat{y})$ then it is called **R-Knot-Node** insertion problem.
- If $\hat{z}_{n,*} = f_1(x_n, \hat{y})$, $\hat{t}_{n,*} = f_2(x_n, \hat{y})$ for all $n = 0, 1, \ldots, N$, $\hat{z} = f_1(\hat{x}, \hat{y})$ and $\hat{t} = f_2(\hat{x}, \hat{y})$ then it is called **R-Knot-Knot** insertion problem.
- If $\hat{z}_{n,*} \neq f_1(x_n, \hat{y})$ and $\hat{t}_{n,*} \neq f_2(x_n, \hat{y})$ for some $n = 0, 1, \ldots, N$ then it is called **R-Node-Node** insertion problem.

**Method 3**: In this method, both row and column of new points are inserted in the given interpolation data.

- If $\hat{t}_{n,*} = f_2(x_n, \hat{y})$ for all $n = 0, 1, \ldots, N$, $\hat{t}_{*,m} = f_2(\hat{x}, y_m)$ for all $m = 0, 1, \ldots, M$ and $\hat{t} = f_2(\hat{x}, \hat{y})$ but $\hat{z}_{n,*} \neq f_1(x_n, \hat{y})$ for some $n = 1, 2, \ldots, N$ or $\hat{z}_{*,m} \neq f_1(\hat{x}, y_m)$ for some $m = 1, 2, \ldots, M$ or $\hat{z} \neq f_1(\hat{x}, \hat{y})$ then it is called **RC-Node-Knot** insertion problem.
- If $\hat{z}_{n,*} = f_1(x_n, \hat{y})$ for all $n = 0, 1, \ldots, N$, $\hat{z}_{*,m} = f_1(\hat{x}, y_m)$ for all $m = 0, 1, \ldots, M$ and

TABLE I
VALUE OF $z_{n,m}$ AT $(x_n, y_m)$ IN A SAMPLE INTERPOLATION DATA

| $y_m/x_n$ | 0 | 8 | 22 | 42 | 50 |
|---|---|---|---|---|---|
| **0** | 23 | 20 | 20 | 31 | 18 |
| **15** | 36 | 26 | 24 | 24 | 23 |
| **35** | 26 | 26 | 26 | 26 | 25 |
| **40** | 32 | 29 | 36 | 36 | 30 |

TABLE II
VALUE OF $t_{n,m}$ AT $(x_n, y_m)$ IN GENERALIZED INTERPOLATION DATA

| $y_m/x_n$ | 0 | 8 | 22 | 42 | 50 |
|---|---|---|---|---|---|
| **0** | 20 | 60 | 37 | 57 | 45 |
| **15** | 29 | 22 | 16 | 38 | 68 |
| **35** | 19 | 58 | 36 | 63 | 71 |
| **40** | 69 | 82 | 44 | 35 | 15 |

$\hat{z} = f_1(\hat{x}, \hat{y})$ but $\hat{t_{n,*}} \neq f_2(x_n, \hat{y})$ for some $n = 1, 2, \ldots, N$ or $\hat{t_{*,m}} \neq f_2(\hat{x}, y_m)$ for some $m = 1, 2, \ldots, M$ or $\hat{t} \neq f_2(\hat{x}, \hat{y})$ then it is called **RC-Knot-Node** insertion problem.

- If $\hat{z_{n,*}} = f_1(x_n, \hat{y})$, $\hat{t_{n,*}} = f_2(x_n, \hat{y})$ for all $n = 0, 1, \ldots, N$, $\hat{z_{*,m}} = f_1(\hat{x}, y_m)$, $\hat{t_{*,m}} = f_2(\hat{x}, y_m)$ for all $m = 0, 1, \ldots, M$, $\hat{z} = f_1(\hat{x}, \hat{y})$ and $\hat{t} = f_2(\hat{x}, \hat{y})$ then it is called **RC-Knot-Knot** insertion problem.

- If $\hat{z_{n,*}} \neq f_1(x_n, \hat{y})$ and $\hat{t_{n,*}} \neq f_2(x_n, \hat{y})$ for some $n = 0, 1, \ldots, N$, $\hat{z_{*,m}} \neq f_1(\hat{x}, y_m)$ and $\hat{t_{*,m}} \neq f_2(\hat{x}, y_m)$ for some $m = 0, 1, \ldots, M$ or $\hat{z} \neq f_1(\hat{x}, \hat{y})$ and $\hat{t} \neq f_2(\hat{x}, \hat{y})$ then it is called **RC-Node-Node** insertion problem.

## V. EXAMPLES

LET $\Delta = \{(x_i, y_j, z_{i,j}, t_{i,j}) : i = 0, 1, \ldots, N$ and $j = 0, 1, \ldots, M\}$ where $z_{i,j}$ is given by Table I and $t_{i,j}$ is given by Table II be a sample generalized interpolation data. Fig. 1 is created with $\alpha_{n,m} = 0.3$, $\beta_{n,m} = 0.2$ and $\gamma_{n,m} = 0.5$. Figs. 2 and 3 are simulations of CHFIS generated corresponding to insertion of set of nodes $\Gamma_1 = \{(30, 0, 12, 23), (30, 15, 25, 56), (30, 35, 31, 12), (30, 50, 40, 76)\}$ and $\Gamma_2 = \{(0, 20, 22, 12), (8, 20, 43, 45), (22, 20, 67, 76), (42, 20, 12, 21), (50, 20, 55, 55)\}$ in the $\Delta$ respectively. Fig. 4 is obtained by inserting $\Gamma_1$, $\Gamma_2$ and $(30, 20, 55, 99)$ in the $\Delta$.

## VI. CONCLUSION

THE impact of node insertion on the associated non-diagonal IFS and CHFIS is investigated in this paper. In bivariate case, there are the three different ways of inserting new points such as inserting a row of new points, inserting a column of new points and inserting both row and column of new points. For each of these methods, it is proved that the new non-diagonal IFS constructed using the new set of interpolation data give rise to a new CHFIS. Further, for each mode of insertion of nodes, the problem is further classified into four types of insertion according to inserted nodes' values.
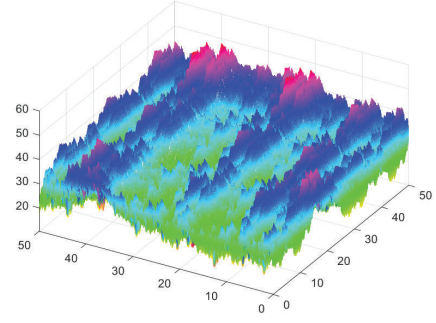


Fig. 1. Original Surface
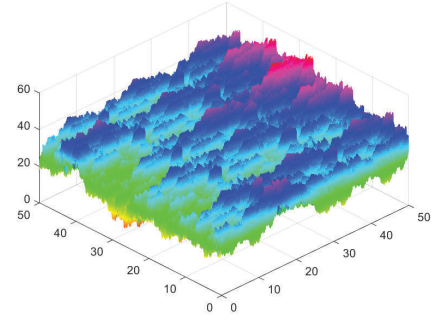


Fig. 2. Insertion of nodes $\Gamma_1$
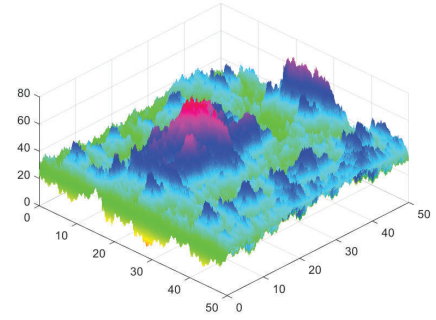


Fig. 3. Insertion of nodes $\Gamma_2$
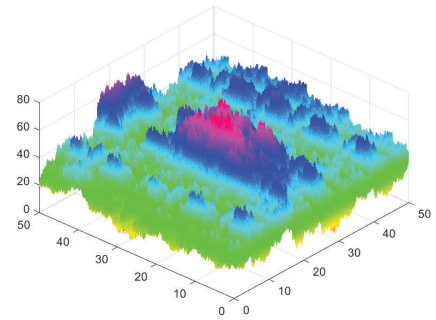


Fig. 4. Insertion of nodes $\Gamma_1 \bigcup \Gamma_2$

So, there are 12 kinds of node insertion in bivariate case as opposed to only 4 cases in single variable. These 12 cases also indicate whether the new set of points are inserted along a row or a column or in both. In future, the effect of insertion of nodes in smoothness and fractal dimension will be studied.

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# Vibration Analysis of Stepped Nanoarches with Defects

J. Lellep, S. Mubasshar

*Abstract*—A numerical solution is developed for simply supported nanoarches based on the non-local theory of elasticity. The nanoarch under consideration has a step-wise variable cross-section and is weakened by crack-like defects. It is assumed that the cracks are stationary and the mechanical behaviour of the nanoarch can be modelled by Eringen's non-local theory of elasticity. The physical and thermal properties are sensitive with respect to changes of dimensions in the nano level. The classical theory of elasticity is unable to describe such changes in material properties. This is because, during the development of the classical theory of elasticity, the speculation of molecular objects was avoided. Therefore, the non-local theory of elasticity is applied to study the vibration of nanostructures and it has been accepted by many researchers. In the non-local theory of elasticity, it is assumed that the stress state of the body at a given point depends on the stress state of each point of the structure. However, within the classical theory of elasticity, the stress state of the body depends only on the given point. The system of main equations consists of equilibrium equations, geometrical relations and constitutive equations with boundary and intermediate conditions. The system of equations is solved by using the method of separation of variables. Consequently, the governing differential equations are converted into a system of algebraic equations whose solution exists if the determinant of the coefficients of the matrix vanishes. The influence of cracks and steps on the natural vibration of the nanoarches is prescribed with the aid of additional local compliance at the weakened cross-section. An algorithm to determine the eigenfrequencies of the nanoarches is developed with the help of computer software. The effects of various physical and geometrical parameters are recorded and drawn graphically.

*Keywords*—Crack, nanoarches, natural frequency, step.

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# Number Theory Solution and Exact Count of Non Primes

Mostafa Yacoup Abdellatif Mahmoud

Prime Numbers exclusive formula

For counting non-prime numbers due to the effect of consecutive primes starting with prime three, and answer the questions about the patterns formed within the distribution of prime numbers

It is easy to conclude that the prime number must end with one of these numbers (1,3,7,9) with exception of number 2 and number 5, since the number ended with (2,4,8,0,5) can not be a prime number, since it is divisible by 2 or 5

So the prime number probabilities are contained in the following series of odd numbers(with exception of number 2 and number 5)

I will call this series PTbP(probably to be prime)

(, 3 , 7,  9,
11,13,17, 19,
21,23,27,29,
31,33 ,37, 39
41,43,47, 49
And so on….

A set of successive prime numbers=n primes
[3,7,11,13,…………………………………………………………
…..,f] that belong to series PTbP participates in the formation of the non-prime numbers in a certain range equal to the product of those consecutive primes multiplied by ten.

S=product of those primes $\prod_{i=3}^{i=f} (i))$

Range= $10 \times S$

Number of non-primes created by the effect of those consecutive primes within the range $10 \times S$

$$=[(4 \times \frac{S}{3})+$$
$$(\sum_{j=7}^{j=f=last\ prime} (4 \times (S/j) \times$$
$$\prod_{i=3}^{i=previous\ prime\ of\ current\ j\ prime} (\frac{i-1}{i})))$$
$$-(n)]$$

The first term (4×S/3)represents the count of
 non-primes created by prime number 3 within the range
 =10 × S   including the prime three itself

the second term

$$(\sum_{j=7}^{j=f} (4 \times (S/j) \times$$
$$\prod_{i=3}^{i=previous\ prime\ of\ current\ j\ prime} (\frac{i-1}{i})))$$

represent the count of non-primes created by prime numbers after the prime3 within the range =10 × S   including the

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consecutive primes, and that explains the third term subtracting n (number of consecutive primes start from prime number 3)
and if we didn't subtract n from that formula it will give the exact count of numbers that are divisible by those consecutive primes
within that range 10 × S   within the series PTbP

there is a common thing between those numbers in this series PTbP mentioned above, and to explain that thing, I will call this concept "the number cycle which is as the following
If we multiply any number  N from this series by ten and then throw out this number N through this range N*10 the result will be only an odd number belonging to the mentioned series at certain  4 ratios ( it explain the number 4 in the general formula mentioned above)from that range (N*10), those ratios are constant and  their values are 0.1,0.3,0.7,0.9
For example  number 3, if multiplied 3*10 we will get range 30 for this particular number
,and the throwout result belong to the mentioned series at 0.1*30=3,and 0.3*30=9,and 0.7*30=21,and 0.9*30=27,and if we continue to the next cycle it works     i.e 3*11=33,3*13=39,3*17=51,3*19=57
And so on.
It is logical and can be easily explained because the result from multiplying the one's place( that contains only 1,3,7,9) in any number belonging to this series must belong to this series.
 the multiples of number 3 will cancel the probability of four numbers in this series in each number cycle after the first number cycle for number three since 3 is a prime number in the first number cycle, and only 3 probabilities in the first cycle are canceled.
The same for number 7and the other numbers in the mentioned series if multiplied 7*10 we will get a range of 70 for this particular number
, and the throw-out result belongs to the mentioned series at 0.1*70=7, 0.3*70=21,
 0.7*70=49,and 0.9*70=63

randomness in the prime numbers
There is no randomness in the prime numbers

Ex The effect of  consecutive prime numbers[3,7,11,13]
S= 3×7×11×13 = 3003
Range=10 ×3003= 30030
Effect of number three in the first cycle including prime three
4×3003/3=4004
Effect of number 7 in the first cycle including prime seven
= 4×3003/7×2/3 = 1144

Effect of number 11 in the first cycle including prime eleven
= $4 \times 3003/11 \times 2/3 \times 6/7 = 624$
Effect of number 13 in the first cycle including prime thirteen
= $4 \times 3003/13 \times 2/3 \times 6/7 \times 10/11 = 480$
As we see the effect of the prime in creating non-primes within that defined range reduces according to this amazing formula, the most effective one is prime three, then prime seven, and so on, the total number of non-primes within series PTbP in the first cycle =6252-4=6248 non-prime
And =6252 non-prime in the other cycles

I make a conclusion with python code attached(that can be executed with PyCharm community) that is the primes less than 60 million produce around 92 % of non-primes within their range S ×10
Which is a really big number
Where S=the product of the first 60 million prime (except 2,5).

So my research solves the problem of the regular pattern formed within the distribution of prime numbers, those patterns occur because of the behavior of consecutive prime numbers starting from 3 and creating a uniform pattern of non-primes that are repeated regularly each cycle after the first cycle that contains the primes , each cycle= Range of those consecutive prime numbers= S ×10.

# Optimal Pricing Mechanism for Non-Storable Goods: The Power of Opaque Products

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**ABSTRACT**

In this paper, we develop a theoretical model to analyze firms' optimal pricing mechanism for non-storable goods. With non-storable goods, firms may be interested in introducing opaque products in order to have two different markets: the transparent market and the opaque market. This may allow firms to sell all their non-storable goods, discriminate prices between markets, and maximize revenues. We prove that in a situation of low demand in the transparent market, if all consumers are risk neutral or risk loving, introducing opaque products is always the most profitable strategy for the firm. However, if consumers are risk averse, the firm needs to offer opaque products with an additional discount. We analyze under which circumstances selling opaque products with such a discount is the optimal pricing strategy. Throughout the paper, we use airlines' pricing strategy as an application for non-storable goods (flights), opaque products (blind tickets), and continuously changing demand (as it is nowadays the case in the air transport industry due to the Covid-19 pandemic).

**KEYWORDS:** Opaque products, risk attitude, expected utility, pricing strategy.

**JEL CLASSIFICATION:** D42, D81, L11, L93.

## 1. Introduction

Opaque products can be defined as goods whose characteristics or attributes are hidden purposely to consumers until the payment has been done. They are usually introduced in non-storable goods markets, based on the idea of maximizing revenues (revenue management), anticipating the distressed inventory of goods and, consequently, creating two differentiated and independent markets. Opaque products are used as a price discrimination mechanism (Jiang, 2007) or a marketing practice (Anderson & Celik, 2020), that consists of lowering prices due to the lack of information given to consumers. According to Cossa & Tappata (2013), on average, opaque booking allows customers to obtain a 44% discount with respect to the transparent rate.

The air transport industry is a clear example of non-storable goods markets where opaque products have been sold. The rationale of this strategy is that the opaque products can create new

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demand, different from the existing market that sells regular tickets, and can secure additional revenues while maintaining the existing ones (Ko & Song, 2020).

The concept of opaque products was first introduced in the air transport industry by Germanwings, a low-cost carrier wholly-owned subsidiary of Lufthansa, and named it as "blind booking". This practice implies that customers buy non-refundable tickets without knowing the destination and the airline they are paying for. The only information they have at the moment of purchase is the set of possible destinations, based on their preferences, and it is only after the payment when the final destination is revealed. Therefore, an opaque good can be any of a few clearly identified base goods that are horizontally differentiated substitutes and that are independently available for purchase (Balestrieri *et al*., 2021).

Over the years, different companies, mainly intermediaries, have implemented this new pricing practice creating opaque packages that include not only flights to several destinations, but also accommodation and car rentals. Some of them are Drumwit, FlyKube, Hotwire, Randombox, Priceline, Waynabox and WowTrip.

Some variants of opaque products include variable opaque products that enable customers to influence the level of opaqueness (Post, 2010). For instance, customers can decrease the level of uncertainty by deselecting a certain number of characteristics of the product, such as the type of journey by paying an extra fee.

According to Martínez *et al*. (2017), the general mechanism of opaque selling in the airline industry is as follows. First, customers choose the dates they want to travel, and the system provides different travel options. Then, in the case of variable opaque products, customers can reduce some uncertainty by unselecting destinations. Finally, they pay for the package which has a fixed price independently of the destination and the travel dates. However, before payment, some companies offer additional services such as extra luggage and travel and cancellation insurance what supposes an increase in the fixed price of the package.

Even though the final destination is revealed after payment, companies differ in the timing of solving the uncertainty. Some companies reveal the final destination immediately after payment or 48-72 hours before the trip starts, while others such as WowTrip provides customers, some days before the journey, information about weather conditions of the destination, the luggage needed, and the departure terminal and time, and it is in the airport where they actually know the final destination.

One of the main reasons for the implementation of this new pricing practice is to manage the distressed inventory. In the case of the airline industry, goods are perishable in the sense that they have to be sold before a certain time and have no value if they remain unsold (Jerath *et al*., 2010). According to Gallego *et al*. (2008), the distressed inventory of airlines ranges from 20 to 30 percent. Nowadays, this figure is higher due to the spread of Covid-19.

Other pricing mechanisms, such as last-minute sales, are often used by airlines to deal with distressed inventory. Although in the short term, it might increase revenues, in the long term the effect of the strategy is that consumers anticipate the discounted tickets, delaying the purchase from the regular market and, therefore, reducing the revenues for the company (Jerath *et al*., 2010). However, opaque selling implies that besides offering each base product individually for sale, the airline can also design and sell any number of lotteries that award one of the base products as the final prize, but the consumer cannot observe the outcome until after purchase (Anderson & Celik, 2020). Therefore, the main purpose of opaque selling is to create a new market on which new customers buy the distressed inventory by lowering the prices due to the lack of information, but without altering the already existing market.

We depart from the idea that opaque products in the airline industry can be described as a lottery whose prizes are mainly flights to destinations with unsold capacity, that may satisfy the following conditions. On the one hand, apart from the unsold capacity, the lotteries must contain a certain number of seats of the most demanded destinations in order to encourage customers to buy them. On the second hand, the lotteries may allow to separate two markets, the regular market (under perfect information conditions) and the opaque one, generating an entirely new demand that supposes an additional source of revenue to the airline and avoiding the cannibalization effect (Ko & Song, 2020). Thus, the regular market is composed of customers with strong preferences and, therefore, high willingness to pay for a destination, and the discounted one is made of customers which are price-sensitive and have weak preferences over the destinations, and that otherwise would not buy the flights.

Cannibalization occurs when travelers who normally purchase from the regular channel (under perfect information conditions) at a higher price, end up purchasing in the opaque channel at a lower price (Savira & Suharsono, 2013). For this reason, a fundamental premise when attempting to exploit new markets is that these markets are genuinely new and that is not simply a buy-down effect from the existing market (Post, 2010).

Previous research on opaque selling in the airline industry is mostly devoted to apply the Hotelling model (Hotelling, 1929), based on horizontal differentiation and assuming that products have similar qualities (Shapiro & Shi, 2008).[1] Other methodologies include a Heuristic model to optimize the price that an airline should charge for a variable opaque product of a particular opaqueness (Post, 2010), or an algorithm of variable opaque products (Ko & Song, 2020).

The main results achieved by the literature imply that opaque selling should be encouraged when customers are heterogeneous since it generates an increase in social welfare (Jiang, 2007), that airlines may have incentives to contract an opaque intermediary under circumstances of brand loyalty, and that its success relies on non-refundable and non-transferable purchases (Fay, 2008). Moreover, lotteries can be considered as a profitable tool to increase revenues for a monopolist provider who sells two perfect substitute goods (Thanassoulis, 2004) which have large differences in the valuations (Pavlov, 2011), instead of posting a "take-or-leave-it" single price (Riley & Zeckhauser, 1983).

Jerath *et al*. (2010) analyze the main similarities and differences between opaque selling and other price discrimination strategies, such as versioning and damaged goods. They are similar in the sense that the same product is sold both through a transparent and an opaque channel (Jerath *et al*., 2010). However, they differ in that opaque selling requires an alternative competing product and that, under opaque selling, there is a group of consumers who get the same or more utility, those who are awarded the most preferred destination.

The contribution of this paper to the academic literature is twofold: First, we conceive opaque selling as a practice of horizontally differentiated substitute goods on which the risk attitude of consumers plays a key role. To the best of our knowledge, theoretical models of opaque products that include risk attitude are scarce, assuming only risk neutrality or a risk preference factor (Bai *et al*., 2015), but not risk averse or risk loving individuals, as we do in this paper. As Fay & Xie (2008) state, "attitudes toward probabilistic goods depend not only on the strength of one's preference, but also on one's disposition toward risk". Thus, differently from the previous literature, we consider that passengers behave as maximizers of their expected utility (Von Neumann-Morgenstern utility function) that provides each of the destinations. Second, taking into

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[1] See, for instance, Jiang (2007), Fay & Xie (2008), Balestrieri *et al*. (2015), or Anderson & Celik (2020).

account consumers' risk attitude, we obtain the conditions that must be satisfied to guarantee the economic success of opaque selling under different market conditions.

Our main results suggest that the success and optimality of opaque products are intimately related to consumers' risk attitude. Thus, airlines should take into consideration the risk attitude of the consumers when designing packages of opaque selling. Moreover, in order to avoid cannibalization, but at the same time create an attractive product, the lotteries must include both air tickets of the most preferred destination and unsold seats of the least preferred destination. If the market segment of opaque selling is composed by risk neutral and risk loving individuals, introducing a parallel market of opaque products is always optimal. Nonetheless, if consumers are risk averse, the firm needs to offer opaque products with an additional discount and, depending on the amount of the discount and other characteristics of the market, introducing a parallel market of opaque products may not be optimal.

The rest of the paper is organized as follows. Section 2 includes the base theoretical model, assuming a monopolist airline that sells flights to two destinations and two types of consumers. In this context, we look for the optimal pricing strategy under different market situations. Section 3 provides some numerical examples in order to illustrate the main results of the paper. Finally, Section 4 summarizes the main results and conclusions.

## 2. The model

Suppose a market operated by a monopolist airline that offers flights to two possible destinations: destination $A$ and destination $B$. In such a market, there are two types of consumers, denoted by type 1 and type 2, with different willingness to pay for traveling to any of these destinations. In particular, consumers have either a high willingness to pay, $H$, or a low willingness to pay, $L$, with $H > L$.

There are $N_1$ type 1 individuals and $N_2$ type 2 individuals in this market. Type 1 and type 2 consumers have different preferences over destinations. Type 1 consumers prefer to travel to destination $A$ rather than to destination B, that is, they have a high willingness to pay, $H$, for destination $A$, and a low willingness to pay, $L$, for destination $B$. On the contrary, type 2 consumers prefer destination $B$ and, therefore, they have a high willingness to pay, $H$, for destination $B$ and a low willingness to pay, $L$, for destination $A$. All consumers have a unitary demand.

The utility functions for each type of consumers, 1 and 2, when traveling to each destination, $A$ and $B$, are given by the following expressions:

$$U_1^A = (M + H - P_A)^{\alpha_i}, U_1^B = (M + L - P_B)^{\alpha_i}, i = 1, \dots, N_1. \tag{1}$$

$$U_2^A = (M + L - P_A)^{\beta_j}, \; U_2^B = (M + H - P_B)^{\beta_j}, j = 1, \dots, N_2, \tag{2}$$

where $M$ represents individuals' initial income, and $P_A$ and $P_B$ denote the ticket price paid by consumers when flying to destination $A$ and $B$, respectively. $\alpha_i$ and $\beta_j$ are positive parameters associated with the risk attitude of each consumer. In particular, if $\alpha_i$ (or $\beta_j$) is lower than 1, consumers are risk averse; if $\alpha_i$ (or $\beta_j$) is equal to 1, they are risk neutral; and if $\alpha_i$ (or $\beta_j$) is greater than 1, consumers are risk loving. The subindexes $i$ and $j$ imply that individuals of the same type have the same preferences over destinations, but they may have different risk attitude.

For the sake of simplicity, we also make the following assumptions. First, the marginal operating cost for the airline is assumed to be constant and normalized to zero. Second, the capacity of the aircrafts used for both destinations $A$ and $B$ is the same and equal to $K$. Third, independently of the number of passengers that may be willing to travel to destination $A$ and $B$, both routes are operated. Fourth, the air carrier knows exactly the willingness to pay of both types of consumers

for both destinations, that is $H$ and $L$. However, it cannot distinguish the type of the consumer that is buying each ticket (adverse selection problem) and, thus, it cannot discriminate prices according to consumers' type. Finally, we assume that the airline has all the bargaining power and, thus, charges the maximum price that consumers are willing to pay. For such a maximum price, consumers are indifferent between traveling or not, but we assume that they decide to travel.

Once we have described the main assumptions of the model and the basic notation, let us study the different market situations and the possible strategies that the airline should adopt in order to maximize its profits.

### 3.1. Case 1: There is an excess demand of passengers with high willingness to pay in both routes: $N_1 \geq K$ and $N_2 \geq K$

Suppose an initial scenario in which there is an excess demand of passengers with high willingness to pay in both routes, what implies that $N_1 \geq K$ (with $K$ being the aircraft capacity in destination $A$), and $N_2 \geq K$ (with $K$ being the aircraft capacity in destination $B$). In this case, the airline sets a price equal to the maximum willingness to pay in both routes $P_A = P_B = H$, and $K$ type 1 consumers buy a ticket to travel to destination $A$ and $K$ type 2 consumers buy a ticket to travel to destination $B$.

***Proposition 1:*** *If there is an excess demand of passengers with high willingness to pay in both routes (Case 1), the optimal strategy for the air carrier is to charge prices equal to the maximum willingness to pay in both destinations, $P_A = P_B = H$, and the airline's optimal profits are equal to $\pi_0 = 2KH$.*

This situation is the most favourable situation for the airline since in both destinations there is an excess demand of passengers with the highest willingness to pay and it manages to sell all the tickets at the highest price.

### 3.2. Case 2: One of the destinations has a demand of passengers with high willingness to pay lower than the aircraft's capacity, while the other destination faces a situation of excess demand: $N_i < K, N_j \geq K$, and $N_i + N_j \geq 2K$, with $i \neq j$ ; $i, j = 1, 2$.

Let us consider now the case in which one of the destinations has a demand of passengers with high willingness to pay lower than the aircraft's capacity, while the other destination faces a situation of excess demand. For instance, suppose that destination $A$ is the one with lower demand, that is $N_1 < K$, while destination $B$ is the most demanded one, that is $N_2 \geq K$.[2] In the same way, let us assume that all the available seats of destination $A$ can be plenty covered by all the passengers that prefer to travel to destination $B$ but are not able to do so due to the excess demand: $N_2 + N_1 \geq 2K$.

Under these assumptions, the airline needs to decide the best strategy in terms of pricing. Although the airline knows consumers' willingness to pay for both destinations, it faces an adverse selection problem, due to the fact that it cannot distinguish consumers' types. In other words, the airline does not have any way of knowing the type of the passenger, type 1 or type 2, that actually purchases a ticket for each of the destinations. Under these conditions, three main pricing strategies can be identified.

***Strategy 1:*** *Set $P_A = P_B = H$.*

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[2] The same reasoning can be applied in the opposite situation, where $N_1 \geq K$ and $N_2 < K$.

*Strategy 1* implies charging both type of consumers a ticket price based on their maximum willingness to pay. In the case of the destination $B$, a situation of sold out is initially achieved since there is an excess demand ($N_2 \geq K$). In other words, $K$ type 2 consumers buy a ticket for destination $B$, although there are still ($N_2 - K$) type 2 consumers who have a high willingness to pay for destination $B$ but are unable to travel because of the lack of capacity. On the contrary, in destination $A$ the airline is only able to sell $N_1$ seats which is lower than $K$, but these seats cannot be covered by type 2 individuals due to the fact that their willingness to pay for destination $A$ is lower than the price charged by the airline, that is $L < H$.

Under this strategy the airline leaves free $K - N_1$ seats of destination $A$, and the airline's profits under this strategy are given by the following expression:

$$\pi_1 = N_1 H + KH. \tag{3}$$

**Strategy 2:** *Set $P_A = L$ and $P_B = H$.*

*Strategy 2* implies reducing the price of destination $A$ in order to sell all the available seats, $K$. Notice that all type 1 consumers now buy $N_1$ tickets of destination $A$ at a lower price in comparison with *Strategy 1*, that is, $L$. In the case of type 2 passengers, they buy $K$ tickets for destination $B$ at the same price as in *Strategy 1*. Since the destination $A$ is now charged at a price equal to the willingness to pay of type 2 individuals, $L$, the ($N_2 - K$) passengers that are unable to travel to destination $B$ because of the lack of capacity now decide to buy tickets to destination $A$. As $N_2 + N_1 \geq 2K$, under this strategy, the company sells $2K$ air tickets, and its profits are given by:

$$\pi_2 = KL + KH. \tag{4}$$

By comparing the profits given by expressions (3) and (4), we can state the following proposition.

**Proposition 2:** *In Case 2, Strategy 1 will be more profitable for the airline as long as $N_1 H \geq KL$. On the contrary, Strategy 2 will be dominant if $KL \geq N_1 H$.*

*Strategy 1* imply a trade-off between decreasing prices in order to increase the demand of destination $A$ and keeping high ticket prices but uncovering the aircraft capacity in destination $A$. However, the airline may use an even better pricing strategy than *Strategy 1* or *Strategy 2*, that would allow it to sell all the tickets in destination $A$ without reducing the price to the $N_1$ type 1 consumers.

**Strategy 3:** *Create two markets: the transparent market and the opaque market. In the transparent market, set $P_A = P_B = H$. In the opaque market, set $P_R$.*

Opaque products consist of creating a new market. Hereinafter, we will differentiate two markets: the transparent market where individuals can directly buy tickets under perfect information conditions and the opaque market where, at the moment of purchasing, consumers do not know which of the destinations are actually buying.

Under this strategy the airline charges the tickets of both destinations $A$ and $B$ in the transparent market at a price equal to $H$ but extracts some seats, $N_R^B$, of destination $B$ from the transparent market in order to create a lottery in the opaque market composed by the $K - N_1$ seats left of destination $A$, denoted by $N_R^A$, and the $N_R^B$ seats subtracted from destination $B$. The aim of this lottery is to attract the ($N_2 - K$) type 2 consumers who are left out of the transparent market of destination $B$.

Type 1 and type 2 individuals maximize their expected utility, $E[U_1]$ and $E[U_2]$, which is described by the Von Neumann-Morgenstern utility function that depends on the probability of each destination, individuals' risk attitude, and the price of the lottery, $P_R$.

$$E[U_1] = \frac{N_R^A}{N_R^A + N_R^B} [M + H - P_R]^{\alpha_i} + \frac{N_R^B}{N_R^A + N_R^B} [M + L - P_R]^{\alpha_i} \tag{5}$$

$$E[U_2] = \frac{N_R^A}{N_R^A + N_R^B} [M + L - P_R]^{\beta_j} + \frac{N_R^B}{N_R^A + N_R^B} [M + H - P_R]^{\beta_j}. \tag{6}$$

The price charged by the airline for the lottery $P_R$ depends on the probability of each destination in the lottery, the maximum willingness to pay of type 2 consumers for destination $A$ and destination $B$, respectively, and a discount $D \geq 0$:

$$P_R = \frac{N_R^A}{N_R^A + N_R^B} L + \frac{N_R^B}{N_R^A + N_R^B} H - D. \tag{7}$$

The main purpose of *Strategy 3* is to maintain the level of demand of $N_1$ type 1 consumers in destination $A$, and $\left(K - N_R{}^B\right)$ type 2 consumers in destination $B$ in the transparent market. Since due to the capacity constraints, there are $\left(N_2 - K + N_R{}^B\right)$ type 2 consumers that cannot buy a ticket for destination $B$ in the transparent market, the objective of *Strategy 3* is to attract ($N_R{}^A + N_R{}^B$) type 2 individuals to buy the opaque product.

Thus, on the one hand, the lottery must not be attractive for type 1 individuals. This situation can be achieved when the airline chooses $N_R^B$ such that the expected utility that type 1 individuals get from the lottery is less than or equal to the utility they get from buying air tickets for destination $A$ in the transparent market. On the other hand, in order to create an attractive product for type 2 individuals, the airline must set the $N_R^B$ that makes the expected utility of the lottery greater than or equal to the utility they get when they do not fly to any destination.

The expected utility of both type of consumers when they buy the blind ticket, $E[U_1]$ and $E[U_2]$, depends on the probability of destination $A$ and destination B, and on the utility they get from each destination, taking into account the price of the lottery, as it is shown in the following expressions:

$$E[U_1] = \frac{N_R^A}{N_R^A + N_R^B} \left[ M + \frac{N_R^A}{N_R^A + N_R^B} (H - L) + D \right]^{\alpha_i} + \frac{N_R^B}{N_R^A + N_R^B} \left[ M + \frac{N_R^B}{N_R^A + N_R^B} (L - H) + D \right]^{\alpha_i}. \tag{8}$$

$$E[U_2] = \frac{N_R^A}{N_R^A + N_R^B} \left[ M + \frac{N_R^B}{N_R^A + N_R^B} (L - H) + D \right]^{\beta_j} + \frac{N_R^B}{N_R^A + N_R^B} \left[ M + \frac{N_R^A}{N_R^A + N_R^B} (H - L) + D \right]^{\beta_j}. \tag{9}$$

When implementing opaque selling, the airline must set the optimal $N_R^B$ and $D$ that fulfils the following two conditions considering the risk attitude of both type of consumers:

$$G_1(N_R^B) = E[U_1] - M^{\alpha_i} \leq 0. \tag{10}$$

$$G_2(N_R^B) = E[U_2] - M^{\beta_j} \geq 0, \tag{11}$$

where $G_1(N_R^B)$ represents the constraint associated with type 1 consumers, and $G_2(N_R^B)$ the one associated with type 2 individuals. Recall that subindexes $i$ and $j$ represent that, within each type, individuals have the same preferences over destinations, although, within each type, they may have different risk attitude. This is formally stated in the following lemma.

***Lemma 1:*** *In Case 2, the opaque selling technique will be feasible for the airline if it sets the number of seats of destination B included in the lottery $N_R^B$ and the discount in order to attract type 2 individuals D, such that the following two conditions are satisfied: $G_1(N_R^B) \leq 0$ and $G_2(N_R^B) \geq 0$.*

The function $G_2(N_R^B) = 0$ implicitly defines the minimum discount that must be offered in order to guarantee that type 2 consumers buy the lottery. *Lemma 2* summarizes the main characteristics of this minimum discount.

***Lemma 2***: *The minimum discount to be offered to type 2 consumers in the opaque market is higher, the more risk averse these consumers are.*

***Proof:*** See the Appendix. ∎

Notice that type 2 consumers' utility functions are Decreasing Absolute Risk Aversion (DARA) utility functions. Therefore, as individuals' income increases, individuals' coefficient of absolute risk aversion decreases. This means that as individuals' income increases, consumers become less risk averse and, thus, the discount they require to buy the lottery decreases. Figure 1 shows the inverse relationship between the minimum discount and the level of income.

**Figure 1. Inverse relationship between the minimum discount in the opaque market and the level of income of type 2 individuals**
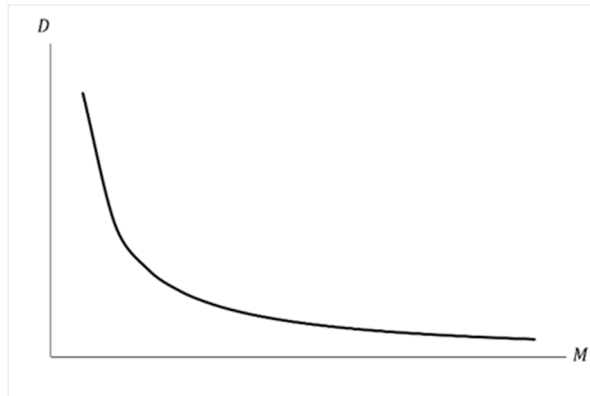


Regarding the attitude toward risk, there is also an inverse relationship between the minimum discount and the parameter $\beta_j$ that measures the risk attitude of type 2 individuals. Recall that if $\beta_j$ is lower than 1, consumers are risk averse; if $\beta_j$ is equal to 1, they are risk neutral; and if $\beta_j$ is greater than 1, consumers are risk loving. The minimum discount required achieves its maximum level in the case of the most risk averse type 2 individuals. The minimum discount is zero when type 2 individuals are risk neutral and achieves negative values in the case of risk loving type 2 consumers. Figure 2 shows this inverse relationship.

**Figure 2. Inverse relationship between the minimum discount in the opaque market and the parameter that measures the risk attitude of type 2 individuals**
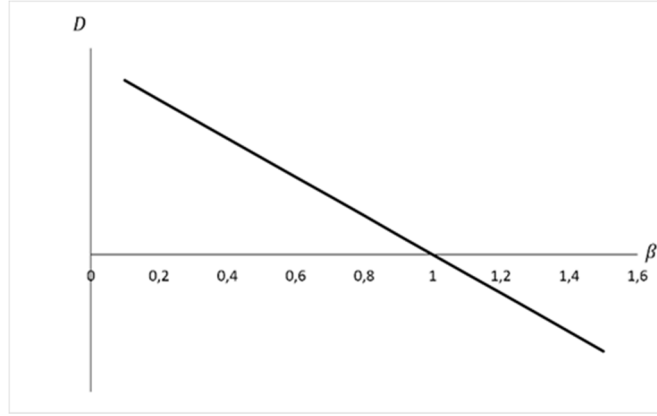
Combining the results of constraints (10) and (11) and assuming different risk attitudes for type 1 and type 2 consumers, we can state the following proposition.

***Proposition 3****: In Case 2, independently of type 1 consumers' risk attitude, if all type 2 individuals are risk neutral or risk loving, the airline can set a discount in the opaque market equal to zero, $D = 0$. In this case, the opaque selling practice will be always feasible.*

***Proof:*** See the Appendix. ∎

If all type 2 individuals are risk neutral or risk loving, the profits that the airline obtains applying *Strategy 3* are given by the following expression:

$$\pi_3 = N_1 H + (K - N_R^B)H + \left(N_R^A + N_R^B\right)\left(\frac{N_R^A}{N_R^A + N_R^B}L + \frac{N_R^B}{N_R^A + N_R^B}H\right), \qquad (12)$$

that can be rewritten as:

$$\pi_3 = (K + N_1)H + N_R^A L. \qquad (13)$$

Notice that airline profits with *Strategy 3* are independent from the number of seats that the airline extracts from the transparent market of destination $B$ to the lottery, $N_R^B$.

***Proposition 4:*** *In Case 2, if all type 2 passengers are risk neutral or risk loving, Strategy 3 will be always the optimal pricing strategy for the airline.*

*Strategy 3* assumes that, in order to be the most profitable one, all type 2 passengers need to be risk neutral or risk loving since, without a discount, risk averse type 2 individuals will not buy the lottery. This assumption can be considered restrictive since, given the heterogeneity of the society, there can be some risk averse type 2 individuals. Denoting by $q$ the proportion of type 2 individuals that are risk neutral or risk loving in the market, let us determine the threshold value for $q$ that makes *Strategy 3* the most profitable for the airline. By definition, $(1 - q)$ is the proportion of risk averse type 2 individuals. The number of tickets sold in the lottery will depend on the proportion of type 2 individuals that are risk neutral and risk loving. Thus, airlines' profits are given by:

$$\pi_{3.1} = N_1 H + (K - N_R^B)H + q(N_R^A + N_R^B)\left(\frac{N_R^A}{N_R^A + N_R^B}L + \frac{N_R^B}{N_R^A + N_R^B}H\right) = (K + N_1)H + qN_R^A L - (1 - q)N_R^B H. \quad (14)$$

In comparison with *Strategy 1*, the profits of *Strategy 3* will be larger if the following constraint is fulfilled:

$$q > \frac{N_R^B H}{N_R^A L + N_R^B H} = c_1. \qquad (15)$$

In comparison with *Strategy 2, Strategy 3* will be the optimal for the airline if the proportion of risk neutral and risk loving type 2 consumers are greater than the following expression:

$$q > \frac{KL + N_R^B H - N_1 H}{N_R^A L + N_R^B H} = c_2. \qquad (16)$$

**Proposition 5:** *In Case 2, there exist two thresholds $c_1$ and $c_2$ for the proportion of type 2 individuals that are risk neutral or risk loving, q, such that: (a) If $KL > N_1 H$ and: (a.1) $c_2 < q$, Strategy 3 dominates; (a.2) $c_1 < q < c_2$, Strategy 2 is the dominant one; (a.3) $q < c_1$, the airline implements Strategy 1. (b) If $KL < N_1 H$ and: (b.1) $c_1 < q$, Strategy 3 dominates; (b.2) $c_2 < q < c_1$, Strategy 1 is the dominant one; (b.3) $q < c_2$, the airline implements Strategy 2.*

All these results are summarized in Figure 3 and Figure 4.

**Figure 3. Optimal pricing strategy for the airline as a function of the proportion of type2 consumers that are risk neutral or risk loving, with $KL > N_1 H$**
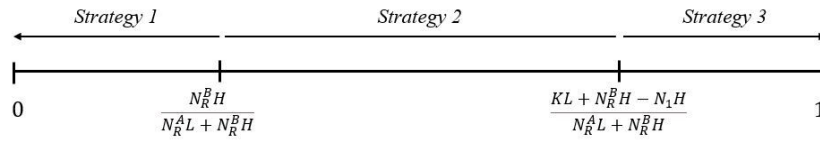


**Figure 4. Optimal pricing strategy for the airline as a function of the proportion of type2 consumers that are risk neutral or risk loving, with $KL < N_1 H$**
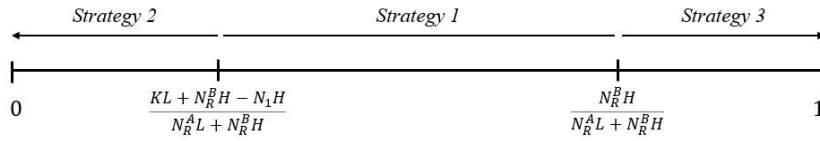


According to these results, the airline should not apply *Strategy 3* when the proportion of type 2 individuals that are risk averse achieves a certain threshold, as it is represented in Figure 3 and Figure 4. Nonetheless, the airline can achieve an equilibrium on which opaque selling supposes the optimal strategy independently of type 2 consumers' risk attitude. In this case, the airline must set a positive discount $D$ in order to attract those risk averse type 2 consumers. Notice that this discount is higher, the higher the proportion of risk averse type 2 individuals is.

The airline must determine, first, the optimal $N_R^B$ that makes the lottery not attractive to type 1 individuals and, second, the optimal discount $D$ that, on the one hand, makes the lottery attractive for risk averse type 2 individuals and, on the other hand, guarantees that type 1 individuals will not change their purchase decision from the transparent market to the opaque one.

The profits that the airline obtains applying a positive discount to the lottery in order to attract risk averse type 2 individuals are given by the following expression.

$$\pi_{3.2} = N_1 H + ((K - N_R^B)H + \left(N_R^A + N_R^B\right)\left(\frac{N_R^A}{N_R^A + N_R^B}L + \frac{N_R^B}{N_R^A + N_R^B}H - D\right). \qquad (17)$$

Notice that in comparison with the profits of *Strategy 3* without a discount $\pi_3$, when implementing a discount to the price of the lottery, the profits not only depend on the discount, but also on the number of seats subtracted from destination $B$, $N_R^B$.

The profits obtained when applying *Strategy 3* with a discount can be rewritten as:

$$\pi_{3.2} = (K + N_1)H + N_R^A L - D\big(N_R^A + N_R^B\big). \tag{18}$$

Despite the conditions that the airline must fulfil when designing the lottery, which are $G_1(N_R^B)$ and $G_2(N_R^B)$, a third constraint appears when implementing a discount, which is associated with the threshold of $D$ from which opaque selling becomes suboptimal in comparison with *Strategy 1* or *Strategy 2*. The value of the threshold depends on $N_1H$ and $KL$. Figure 5 summarizes the critical values of $D$ if $KL > N_1H$.

**Figure 5. Optimal pricing strategy for the airline as a function of the discount *D* in the opaque market, with $KL > N_1H$**
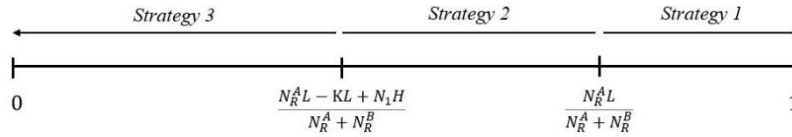


On the extremes, we have the minimum value of $D$ which is equal to zero (when implementing opaque selling without discount) and the maximum value of $D$ which tends to $P_R$. With such a proportion of risk averse type 2 individuals that implies a discount equal to the price of the lottery, $D = P_R$, the airline should not apply opaque selling since, although it sells out both destinations, it will not receive any profit for the seats included in the lottery, $\big(N_R^A + N_R^B\big)$.

In comparison with *Strategy 1*, if the airline based on the risk attitude of type 2 individuals needs to implement a discount larger than $\frac{N_R^A L}{N_R^A + N_R^B}$, *Strategy 3* is suboptimal. In comparison with *Strategy 2*, *Strategy 3* is optimal if the discount is lower than $\frac{N_R^A L - KL + N_1 H}{N_R^A + N_R^B}$. Thus, as far as $KL > N_1H$ and the discount set by the airline is lower than $\frac{N_1 H + N_R^A L - KL}{N_R^A + N_R^B}$ the optimal strategy is opaque selling.

On the contrary, if $KL < N_1H$, then $\frac{N_R^A L}{N_R^A + N_R^B} < \frac{N_R^A L - KL + N_1 H}{N_R^A + N_R^B}$. In comparison with *Strategy 1*, *Strategy 3* is optimal if the discount is lower than $\frac{N_R^A L}{N_R^A + N_R^B}$. According to *Strategy 2*, *Strategy 3* is optimal if the discount implemented does not exceed $\frac{N_R^A L - KL + N_1 H}{N_R^A + N_R^B}$. Thus, *Strategy 3* is optimal as far as the discount is lower than $\frac{N_R^A L}{N_R^A + N_R^B}$. Figure 6 summarizes the critical values of D when $KL < N_1H$.

**Figure 6. Optimal pricing strategy for the airline as a function of the discount D in the opaque market, with $KL < N_1H$**
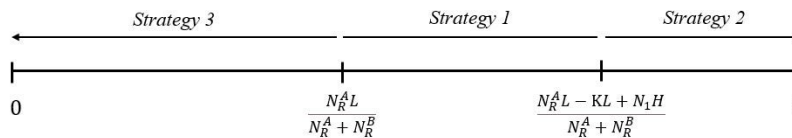


Let us denote by $D^*$ the maximum discount that the airline can implement in order to attract risk averse type 2 individuals whose value can be either $\frac{N_R^A L}{N_R^A + N_R^B}$ or $\frac{N_R^A L - KL + N_1 H}{N_R^A + N_R^B}$ depending on the values of $N_1H$ and $KL$.

$$D^* = \begin{cases} \frac{N_R^A L}{N_R^A + N_R^B}, & if \ KL < N_1 H \\ \frac{N_R^A L - KL + N_1 H}{N_R^A + N_R^B}, & if \ KL > N_1 H. \end{cases} \tag{19}$$

***Proposition 6:*** *In Case 2, independently of type 1 and type 2 consumers' risk attitude, the opaque selling technique will be feasible and optimal for the airline if it sets the number of seats of destination B included in the lottery $N_R^B$, and the discount in order to attract all type 2 individuals D, such that the following three conditions are satisfied: $G_1(N_R^B) \leq 0$, $G_2(N_R^B) \geq 0$, and $D \leq D^*$.*

***Corollary 1:*** *In order to satisfy the three constraints specified in Proposition 6, the level of demand of destination A, $N_1$, needs to be large enough.*

The company may have a minimum level of demand of the destination *A* that guarantees that if it designs a lottery composed by the $N_R^A$ seats from destination *A* and the $N_R^B$ from destination *B* and applies a discount *D*, independently of their risk attitude, all type 1 individuals and all type 2 individuals will continue purchasing in the transparent market and in the opaque market, respectively. Therefore, *Strategy 3* is always the optimal one (see numerical examples in the next section. In particular, see *Case 2*).

Bellow this minimum demand (see *Case 1* in next section), type 1 consumers may still willing to buy in the transparent market (see *Case 1, Scenario 1* and *Scenario 3* in next section), or very risk loving type 1 individuals can deviate from the transparent market since $G_1(N_R^B) \geq 0$ (see *Case 1, Scenario 2* and *Scenario 4* in next section). In this latter case, the profits the airline obtains from type 1 individuals in the transparent market are reduced by the proportion of very risk loving type 1 individuals that decide to buy in the opaque market and, thus, under these very restrictive conditions, *Strategy 3* can become suboptimal (see *Case 1, Scenario 4* in next section). Therefore, if the level of demand in destination *A* is not high enough, the optimality of opaque selling depends on the proportion of very risk averse type 2 individuals, their degree of aversion toward risk, and the proportion of very risk loving type 1 individuals.

## 3. Some numerical illustrations

In order to illustrate the main results of the paper, let us consider some numerical examples based on different markets conditions.

Consider the following scenarios regarding the risk attitude of type 1 and type 2 consumers:

***Scenario 1:*** There are no risk averse type 2 consumers.

***Scenario 2:*** There is a small proportion of very risk averse type 2 individuals (5%), with $\beta_j = 0.1$, and the rest of type 2 consumers are risk neutral or risk loving. There is a large proportion of risk loving type 1 individuals (80%) with $\alpha_i = 1.6$. The other proportion of type 1 consumers (20%) are risk averse or risk neutral.

***Scenario 3:*** There is a large proportion of very low risk averse type 2 individuals (80%), with $\beta_j = 0.8$. The rest of type 2 consumers are risk neutral or risk loving.

***Scenario 4:*** There is a large proportion of very risk averse type 2 consumers (80%), with $\beta_j = 0.1$, and the rest of type 2 consumers are risk neutral or risk loving. There is also a large proportion of very risk loving type 1 individuals (80%), with $\alpha_i = 1.6$. The other proportion of type 1 consumers (20%) are risk averse or risk neutral.

Let us now consider two possible cases, one in which the level of demand in destination *A* is not high enough (Case 1) and one in which the level of demand in destination *A* is high (*Case 2*).

**Case 1: $H = 120$, $L = 90$, $N_1 = 60$, $N_2 = 240$, $K = 150$ and $M = 1000$.**

With these initial market conditions, we look for the optimal pricing strategy for the airline under different scenarios. In the case of *Strategy 3* and some risk averse type 2 consumers in the market, we differentiate between *Strategy 3.1* and *Strategy 3.2*. Both refer to opaque selling, but in the first one no discount is implemented.

Table 1 summarizes the prices, constraints and profits of each strategy for *Case 1*, Scenario *1*.

**Table 1. Optimal pricing strategy for the airline in *Case 1*, *Scenario 1***

|  | *Strategy 1* | *Strategy 2* | *Strategy 3* |
|---|---|---|---|
| **Prices** | $P_A = 120; P_B = 120$ | $P_A = 90; P_B = 120$ | $P_A = 120; P_B = 120$ <br> $D = 0; P_R = 105.08$ |
| **Constraints** | - | - | $G_1(N_R^B) < 0 \quad \forall \alpha_i$ <br> $G_2(N_R^B) > 0 \, \forall \beta_j$ |
| **Profits** | $\pi_1 = 25200$ | $\pi_2 = 31500$ | $\pi_{3.1} = 33299.48$ |

In *Case 1*, *Scenario 1* and regarding *Strategy 3*, no discount is needed since there are no risk averse type 2 individuals. The maximum level of profits is achieved with *Strategy 3*. Thus, the optimal strategy for the airline is to implement opaque selling in order to sell all seats and maximize profits.

Table 2 summarizes the prices, constraints and profits of each strategy for *Case 1*, *Scenario 2*.

**Table 2. Optimal pricing strategy for the airline in *Case 1*, *Scenario 2***

|  | *Strategy 1* | *Strategy 2* | *Strategy 3* | |
|---|---|---|---|---|
|  |  |  | *3.1* | *3.2* |
| **Prices** | $P_A = 120; P_B = 120$ | $P_A = 90; P_B = 120$ | $P_A = 120; P_B = 120$ <br> $D = 0; P_R = 105.08$ | $P_A = 120; P_B = 120$ <br> $D = 0.10; P_R = 104.98$ |
| **Constraints** | - | - | $G_1(N_R^B) \leq 0$ <br> $G_2(N_R^B) > 0$ if $\beta_j > 1$ <br> $G_2(N_R^B) < 0$ if $\beta_j < 1$ | $G_1(N_R^B) < 0$ if $\alpha_i < 1.6$ <br> $G_1(N_R^B) > 0$ if $\alpha_i \geq 1.6$ <br> $G_2(N_R^B) \geq 0; D \leq D^*$ |
| **Profits** | $\pi_1 = 25200$ | $\pi_2 = 31500$ | $\pi_{3.1} = 32348.51$ | $\pi_{3.2} = 27521.38$ |

In *Case 1*, *Scenario 2* and regarding *Strategy 3*, if the airline does not implement a discount (*Strategy* 3.1), the proportion of risk averse type 2 individuals will not have incentives to buy the lottery. However, if it implements the optimal discount $D = 0.10$, $G_1(N_R^B) = 0.18$ for very risk loving type 1 individuals, that is, they have incentives to buy the lottery and will deviate to the opaque market. Thus, in the case of *Strategy 3* when $D = 0$, the constraint $G_2(N_R^B) \geq 0$ is not fulfilled for risk averse type 2 individuals. However, when the airline implements the discount, $G_1(N_R^B) \leq 0$ is not accomplished for all type 1 individuals. Therefore, if the airline does not implement the discount, risk averse type 2 individuals will not buy the lottery while if it implements the discount, very risk loving type 1 individuals will not buy under perfect information conditions. Based on the level of profits, the optimal strategy for the airline is *Strategy 3* without any discount and, therefore, ignoring the little proportion of those very risk averse type 2 individuals.

Table 3 summarizes the prices, constraints and profits of each strategy for *Case 1*, *Scenario 3*.

**Table 3.** Optimal pricing strategy for the airline in *Case 1*, *Scenario 3*

| | Strategy 1 | Strategy 2 | Strategy 3 | |
| --- | --- | --- | --- | --- |
| | | | **3.1** | **3.2** |
| **Prices** | $P_A = 120$; $P_B = 120$ | $P_A = 90$; $P_B = 120$ | $P_A = 120$; $P_B = 120$ <br> $D = 0$; $P_R = 105.08$ | $P_A = 120$; $P_B = 120$ <br> $D = 0.02$; $P_R = 105.06$ |
| **Constraints** | - | - | $G_1(N_R^B) \leq 0$ <br> $G_2(N_R^B) > 0$ if $\beta_j > 1$ <br> $G_2(N_R^B) < 0$ if $\beta_j < 1$ | $G_1(N_R^B) \leq 0\ \forall \alpha_i$ <br> $G_2(N_R^B) \geq 0\ \forall \beta_j$ <br> $D \leq D^*$ |
| **Profits** | $\pi_1 = 25200$ | $\pi_2 = 31500$ | $\pi_{3.1} = 18083.9$ | $\pi_{3.2} = 33295.86$ |

In *Case 1*, *Scenario 3* and regarding *Strategy 3*, if the airline does not implement a discount, it loses a large part of the demand in the opaque market what makes such a strategy suboptimal. However, since type 2 consumers have a low risk aversion, a very low discount, $D = 0.02$, is needed. With this discount, risk loving type 1 individuals have no incentives to deviate from the transparent market. Thus, *Strategy 3* with a discount equal to 0.02 is optimal.

Table 4 summarizes the prices, constraints and profits of each strategy for *Case 1*, *Scenario 4*.

**Table 4. Optimal pricing strategy for the airline in *Case 1*, *Scenario 4***

| | Strategy 1 | Strategy 2 | Strategy 3 | |
| --- | --- | --- | --- | --- |
| | | | **3.1** | **3.2** |
| **Prices** | $P_A = 120$; $P_B = 120$ | $P_A = 90$; $P_B = 120$ | $P_A = 120$; $P_B = 120$ <br> $D = 0$; $P_R = 105.08$ | $P_A = 120$; $P_B = 120$ <br> $D = 0.1$; $P_R = 105.06$ |
| **Constraints** | - | - | $G_1(N_R^B) \leq 0$ <br> $G_2(N_R^B) > 0$ if $\beta_j > 1$ <br> $G_2(N_R^B) < 0$ if $\beta_j < 1$ | $G_1(N_R^B) < 0$ if $\alpha_i < 1.6$ <br> $G_1(N_R^B) > 0$ if $\alpha_i \geq 1.6$ <br> $G_2(N_R^B) \geq 0$; $D \leq D^*$ |
| **Profits** | $\pi_1 = 25200$ | $\pi_2 = 31500$ | $\pi_{3.1} = 18083.9$ | $\pi_{3.2} = 27521.38$ |

In *Case 1*, *Scenario 4 and r*egarding *Strategy 3.1*, with $D = 0$, the constraint $G_2(N_R^B) \geq 0$ is not fulfilled for those very risk averse type 2 individuals and, therefore, the airline loses the demand of these consumers in the opaque market. Under *Strategy 3.1* the optimal discount needed is equal to 0.1 what makes that with the new price of the lottery, very risk loving type 1 individuals will deviate to the transparent market due to $G_1(N_R^B) = 0.18$. Therefore, in the case of *Strategy 3* with $D = 0$ risk averse type 2 individuals will not buy the lottery, while with $D = 0.1$ very risk loving type 1 individuals will deviate to the opaque market. Therefore, in the case of implementing opaque selling, the trade-off is between implementing a discount losing the demand of very risk loving type 1 individuals in the transparent market and not implementing the discount and losing the demand in the opaque market of risk averse type 2 individuals. Thus, under these very restrictive conditions, opaque selling will be suboptimal and *Strategy 2* dominates.

### Case 2: $H = 120$, $L = 90$, $N_1 = 90$, $N_2 = 240$, $K = 150$ and $M = 1000$.

In *Case 2*, we consider similar market conditions than those in *Case 1* except for the case of destination *A* in which the demand of passengers with high willingness to pay is high enough, $N_1 = 90$. For this case, let us consider the less favourable scenarios for *Strategy 3* since there is a large proportion of very risk loving type 1 consumers that may deviate from the transparent market, that is, *Scenario 2* and *Scenario 4*.

Table 5 summarizes the prices, constraints and profits of each strategy for *Case 2*, *Scenario 2*.

**Table 5. Optimal pricing strategy for the airline in *Case 2*, *Scenario 2***

|  | *Strategy 1* | *Strategy 2* | *Strategy 3* | |
|---|---|---|---|---|
|  |  |  | *3.1* | *3.2* |
| **Prices** | $P_A = 120$; $P_B = 120$ | $P_A = 90$; $P_B = 120$ | $P_A = 120$; $P_B = 120$ <br> $D = 0$; $P_R = 105.12$ | $P_A = 120$; $P_B = 120$ <br> $D = 0.10$; $P_R = 105.02$ |
| **Constraints** | - | - | $G_1(N_R^B) \leq 0$ <br> $G_2(N_R^B) > 0$ if $\beta_j > 1$ <br> $G_2(N_R^B) < 0$ if $\beta_j < 1$ | $G_1(N_R^B) \leq 0 \ \forall \alpha_i$ <br> $G_2(N_R^B) \geq 0 \ \forall \beta_j$ <br> $D \leq D^*$ |
| **Profits** | $\pi_1 = 28800$ | $\pi_2 = 31500$ | $\pi_{3.1} = 33563.54$ | $\pi_{3.2} = 34187.42$ |

In *Case 2*, *Scenario 2* and regarding *Strategy 3.1* with a discount equal to 0, the constraint $G_2(N_R^B) \geq 0$ is not fulfilled for those risk averse type 2 individuals. However, in the case of *Strategy 3.2* when the airline implements a discount equal to 0.10, all the three constrains are satisfied, what means that risk loving type 1 individuals have no incentives to deviate from the transparent market. Thus, *Strategy 3* with $D = 0.10$ is optimal.

Table 6 summarizes the prices, constraints and profits of each strategy for *Case 2*, *Scenario 4*.

**Table 6. Optimal pricing strategy for the airline in *Case 2*, *Scenario 4***

|  | *Strategy 1* | *Strategy 2* | *Strategy 3* | |
|---|---|---|---|---|
|  |  |  | *3.1* | *3.2* |
| **Prices** | $P_A = 120$; $P_B = 120$ | $P_A = 90$; $P_B = 120$ | $P_A = 120$; $P_B = 120$ <br> $D = 0$; $P_R = 105.12$ | $P_A = 120$; $P_B = 120$ <br> $D = 0.1$; $P_R = 105.02$ |

| | | | | |
|---|---|---|---|---|
| **Constraints** | - | - | $G_1(N_R^B) \leq 0$ <br> $G_2(N_R^B) > 0$ if $\beta_j > 1$ <br> $G_2(N_R^B) < 0$ if $\beta_j < 1$ | $G_1(N_R^B) \leq 0 \ \forall \alpha_i$ <br> $G_2(N_R^B) \geq 0 \ \forall \beta_j$ <br> $D \leq D^*$ |
| **Profits** | $\pi_1 = 28800$ | $\pi_2 = 31500$ | $\pi_{3.1} = 24023.9$ | $\pi_{3.2} = 34187.42$ |

As it is shown in Table 6, in the case of a discount equal to 0, *Strategy 3.1* is suboptimal. However, as opposed to *Scenario 4*, when the airline implements a discount equal to 0.1, the three constraints are fulfilled, that is, independently from their risk attitude, type 1 consumers purchase under perfect information conditions while type 2 individuals that are not able to buy destination *B* under perfect information conditions buy the lottery. Therefore, *Strategy 3* with a discount equal to 0.1 is optimal.

## 4. Conclusions

Many companies around the world have implemented a new pricing strategy consisting of selling the so-called opaque products. In this paper, we contribute to the already existing literature with a theoretical model that analyses the optimality of this new pricing practice by explicitly considering consumers' risk attitude.

The air transport industry is a clear example of this pricing strategy due to the unperishable nature of the services they provide. Nowadays this selling practice acquires special relevance in the air transport market which faces a continuously changing demand and uncertainty due to the Covid-19 pandemic. In this new context, airlines need to reinvent themselves and design new pricing strategies that allow them to redistribute passengers between destinations with high and low demand and maximize their profits.

In our model, we suppose a multiproduct monopolist that sells air tickets to two different destinations, one with excess supply and the other one with excess demand. In addition, we assume two types of consumers with different willingness to pay for each of the destinations and whose types cannot be observed by the seller due to an adverse selection problem. Under these assumptions and different market situations, we prove that creating a new market of opaque products can be a guarantee of profit maximization.

Regarding revenue management and, in comparison with other pricing strategies, the main advantages of opaque selling are that airlines can maximize their revenues, anticipating the seats left of the less demanded destinations, creating two different and independent markets that can perfectly coexist, avoiding the cannibalization effect, and, therefore, achieving a situation of sold out for all destinations.

Our results suggest that the optimality of opaque products critically depends on consumers' risk attitude, the number of tickets of each destination included in the lottery, the heterogeneity of the destinations included in the lottery, and some other characteristics of the market. Regarding the risk attitude of consumers, we demonstrate that for risk neutral and risk loving individuals, who are not able to buy the most demanded destination in the transparent market due to capacity constraints, opaque products can be a valuable alternative getting at least the same utility than in the transparent market. Moreover, if all consumers are risk neutral or risk loving, introducing opaque selling is always profitable for the airline. For risk averse consumers, the airline needs to offer opaque products with an additional discount and, under some restrictive conditions, this may not be profitable for the airline.

Although this paper analyses different cases and scenarios, further research is needed in this area. Future investigation should be related to the fact that consumers' real willingness to pay may not be observed by firms, and that companies do not always show to consumers the probabilities of each of the products included in the lottery.

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# APPENDIX

***Proof of Lemma 2:*** Type 2 consumers' coefficient of absolute risk aversion is given by: $\rho_2 = -\frac{U_2^{''}}{U_2^{'}}$, where $U_2^{'}$ and $U_2^{''}$ are the first and second derivative of type 2 consumers' utility function with respect to income, respectively. The utility functions for type 2 consumers are Decreasing Absolute Risk Aversion (DARA) utility functions, what implies that as individuals' income increases, their coefficient of absolute risk aversion decreases. That is, as individuals' income increases, they become less risk averse.

The function $G_2(N_R^B) = 0$ implicitly defines the minimum discount that must be offered in order to guarantee that type 2 consumers buy the lottery. Applying the Implicit Function Theorem, we can obtain the derivative of the minimum discount with respect to income:

$$\frac{\partial D}{\partial M} = -\left( \frac{\frac{N_R^A}{N_R^A+N_R^B}\left[M+\frac{N_R^B}{N_R^A+N_R^B}(L-H)+D\right]^{\beta j-1} + \frac{N_R^B}{N_R^A+N_R^B}\left[M+\frac{N_R^A}{N_R^A+N_R^B}(H-L)+D\right]^{\beta j-1} - M^{\beta j-1}}{\frac{N_R^A}{N_R^A+N_R^B}\left[M+\frac{N_R^B}{N_R^A+N_R^B}(L-H)+D\right]^{\beta j-1} + \frac{N_R^B}{N_R^A+N_R^B}\left[M+\frac{N_R^A}{N_R^A+N_R^B}(H-L)+D\right]^{\beta j-1}} \right) < 0. \tag{A.1}$$

The denominator of expression (A.1) is the sum of two positive numbers and, therefore, it is positive. Through numerical simulations, it can be proven that the numerator of expression (A.1) is also positive. Thus, the derivate of the minimum discount with respect to income is negative. Therefore, as individuals' income increases, they become less risk averse and require a lower discount.

Applying the Implicit Function Theorem, we can also obtain the derivative of the minimum discount with respect to the parameter that defines type 2 consumers' risk attitude:

$$\frac{\partial D}{\partial \beta_j} = -\frac{\frac{N_R^A}{N_R^A+N_R^B}\left[M+\frac{N_R^B}{N_R^A+N_R^B}(L-H)+D\right]^{\beta j}\ln\left(M+\frac{N_R^B}{N_R^A+N_R^B}(L-H)+D\right) + \frac{N_R^B}{N_R^A+N_R^B}\left[M+\frac{N_R^A}{N_R^A+N_R^B}(H-L)+D\right]^{\beta j}\ln\left(M+\frac{N_R^A}{N_R^A+N_R^B}(H-L)+D\right) - M^{\beta j}\ln(M)}{\beta_j\frac{N_R^A}{N_R^A+N_R^B}\left[M+\frac{N_R^B}{N_R^A+N_R^B}(L-H)+D\right]^{\beta j-1} + \beta_j\frac{N_R^B}{N_R^A+N_R^B}\left[M+\frac{N_R^A}{N_R^A+N_R^B}(H-L)+D\right]^{\beta j-1}} < 0 \tag{A.2}$$

The denominator of expression (A.2) is the sum of two positive numbers and, therefore, it is positive. Through numerical simulations it can be proven that the numerator of expression (A.2) is also positive. Thus, the derivate of the minimum discount with respect to the parameter that defines type 2 consumers' risk attitude is negative. Therefore, as the parameter that defines type 2 consumers' risk attitude increases, they become less risk averse and require a lower discount.

This completes the proof. ∎

***Proof of Proposition 3:*** Consider that $D = 0.$ Let us start proving that for any risk attitude, all type 1 individuals have no incentives to deviate to the opaque market. In this case, the airline has

to extract a number of seats of destination $B$ from the transparent market, $N_R^B$, greater than or equal to the number of seats available from destination A, that is, $N_R^A$.

The constraint associated with type 1 consumers, $G_1(N_R^B)$, is a linear combination composed by two terms, where the first one is greater than $M^{\alpha_i}$ and the second one is lower than $M^{\alpha_i}$. Considering the nature of this constraint where type 1 individuals must not have incentives to buy the lottery, the term lower than $M^{\alpha_i}$ needs to have a greater impact in the linear combination.

$$\frac{N_R^A}{N_R^A+N_R^B}\left[M + \frac{N_R^A}{N_R^A+N_R^B}(H-L)\right]^{\alpha_i} + \frac{N_R^B}{N_R^A+N_R^B}\left[M + \frac{N_R^B}{N_R^A+N_R^B}(L-H)\right]^{\alpha_i} \le M^{\alpha_i}. \quad (A.3)$$

Notice that both terms of the linear combination are equal but with opposite sign, that is, $(H-L) = -(L-H)$. In order to achieve a result lower than $M^{\alpha_i}$, the impact of the second term needs to be larger than the first one and this is only possible if $N_R^B \ge N_R^A$.

Concerning the constraint associated with type 2 consumers, $G_2(N_R^B)$, again it is a linear combination that depends on passenger $j$'s risk attitude. In the case of risk neutral type 2 individuals $\beta_j = 1$, and the second constraint $G_2(N_R^B)$ is given by:

$$\frac{N_R^A}{N_R^A+N_R^B}\left[M + \frac{N_R^B}{N_R^A+N_R^B}(L-H)\right] + \frac{N_R^B}{N_R^A+N_R^B}\left[M + \frac{N_R^A}{N_R^A+N_R^B}(H-L)\right] \ge M. \quad (A.4)$$

For risk neutral type 2 individuals, any positive number of seats subtracted by the airline from the transparent market, $N_R^B$, will make the second condition feasible since, by solving the inequality derived from the constraint, we obtain that $N_R^A + N_R^B \ge 0$ what implies that $N_R^B \ge -N_R^A$. Thus, any number of seats from destination $B$ set by the airline will fulfil the constraint.

For risk loving type 2 passengers $\beta_j > 1$, and the second constraint $G_2(N_R^B)$ is given by:

$$\frac{N_R^A}{N_R^A+N_R^B}\left[M + \frac{N_R^B}{N_R^A+N_R^B}(L-H)\right]^{\beta_j} + \frac{N_R^B}{N_R^A+N_R^B}\left[M + \frac{N_R^A}{N_R^A+N_R^B}(H-L)\right]^{\beta_j} \ge M^{\beta_j}. \quad (A.5)$$

For risk loving type 2 individuals, any positive number of seats of destination $B$, will make the constraint feasible since, in the same way as in the previous conditions, one of the terms is lower than $M^{\beta_j}$ while the other is greater than $M^{\beta_j}$, since $(H-L) = -(L-H)$. In order to fulfil the constraint, if $N_R^A > N_R^B$ the larger impact of the first term that is lower than $M^{\beta_j}$ will be compensated by the lower impact of the second term that is larger than $M^{\beta_j}$, leading to a result similar to or greater than $M^{\beta_j}$. This completes the proof. ∎

# Technological Developments to Reduce Wind Blade Turbine Levelized Cost of Energy

Pedro M.C. Carneiro, Ricardo Borges, João Pedro Loureiro, Herminio Fernandes

*Abstract*—Wind energy has been exponentially growing over the last years and will allow countries to progress regarding the decarbonization objective. In parallel, the maintenance activities have also been increasing in consequence of ageing and deterioration of the wind farms. The time available for wind blade maintenance is given by the weather window that is based upon weather conditions. Most of the wind blade repair and maintenance activities require a narrow window of temperature and humidity.

Due to this limitation, the current weather windows result only on approximately 35% days/year are used for maintenance, that takes place mostly during summertime. This limitation creates large economic losses in the energy production of the wind towers, since they can be inoperative or with the energy production output reduced for days or weeks due to existing damages. Another important aspect is that the maintenance costs are higher due to the high standby time and seasonality imposed on the technicians. To reduce the relevant maintenance costs of blades and energy loses some technological developments were carried out to significantly improve this reality. The focus of this activity was to develop a series of key developments to have in the near future a suspended access equipment that can operate in harsh conditions, wind rain, cold/hot environment. To this end we have identified key areas that need to be revised and require solutions to be found; a habitat system, multi-configurable roof and floor, roof and floor interface to blade, secondary attachment solutions to the blade and to the tower. On this paper we will describe the advances produced during a national R&D project made in partnership with an end-user (Onrope) and a test center (ISQ).

*Keywords*—Wind Turbine Maintenance, Cost Reduction, Technological Innovations, Wind Turbine Blade.

## I. INTRODUCTION

THE global energy demand is increasing rapidly and as consequence the greenhouse gas emissions are growing at such pace that they are affecting the planet climate [1]. Movements for green energy production are accelerating all around the globe, leading to the development and growth of alternative energy production systems in particular, wind and solar energy. The report "Wind energy in Europe: outlook to 2022-26" prepared by Wind Europe, forecasts that E.U. member states need to meet the target of installing 32 GW of wind power each year in order to reach the target of 40% of their production coming from renewable energy by 2030. According to the study, the installed capacity will grow an average by 17.6 GW per year between 2022 and 2026, thanks to the development of wind farm projects both onshore and offshore. Thus, it is expected that, at the end of this period, wind generation will have increased by 89 GW, to reach the total

figure of 341 GW of installed capacity on the whole continent [2]. The technologies that aim to increase the productivity of wind farms, in particular maintenance tools and equipment, have been receiving attention lately because of the need to reduce levelized cost of energy (LCOE) and increase the diffusion of this solutions and also because the relevance that blades maintenance cost represent on the overall maintenance during turbine life. Currently, the maintenance and NDI inspection are performed either by suspension on cables or through the usage of elevating metallic platforms, but neither one is flexible enough to permit the conduction of these operations easily and at any given time because they are not shielded from the environment [3], [4], [5], [6]. Between rope access and the elevating platforms, the later represent a more robust solution, but none of the available ones at the market, answer to three fundamental problems:

1. the possibility to adapt to any given shape of the geometry of blades avoiding inaccessible areas.
2. the possibility to carry maintenance procedures in adverse climate conditions, like rain, snow, or very hot days.
3. lateral stability to wind gusts and smooth transition of obstacles (tower flanges), especially with windy conditions.

The lack of a solution that solves these problems makes the maintenance activities a seasonal work, being the main consequences energy production loses and higher costs. The technologies under development have the objective of suppressing the existing solutions limitations. The following innovations were defined: creation of a habitat that can sustain harsh meteorologic conditions, by creating a controlled working environment, with controlled temperature and humidity levels; a sealing system connecting the habitat to the blade that will prevent water and external air to enter the habitat, and secondary attachment systems. During the development of the technological innovations, several numerical models, algorithms, and prototypes were created to access the effectiveness of the proposed solutions.

## II. SYSTEM DESCRIPTION

### A. Habitat

The design of a structure able to cover the entire workspace and provide a hermetic environment, in which is possible to control the relative humidity and temperature, is one of the developed solutions. From the performed trade off analysis, it was found that an inflatable solution, due to its low weight,

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easily packing and assembly, is the solution that better fits the requirements. Additionally, this solution is only coupled to the suspended access platform when needed, not interfering with the normal transport and assembly of the platform. The main drivers for the design of the inflatable solution were to minimize the total volume to managed by the environmental control system, allow coupling to suspended access platforms available in the market, sustain wind loads without collapsing and contour interfaces such as hosting points, mobile balconies and emergence hoist. The inflatable habitat is composed by a frame of vertical and horizontal inflatable beams in which textiles panels are attached. The methodology used to size the inflatable structure will be detailed in section III. The management of the inflation pressure and the corresponding control system will also be described.

## B. Roof and sealing system

The development of the interface between the inflatable habitat and the wind turbine blade was the main challenge of this work. The creation of a hermitic connection between the inflatable habitat and the wind turbine blade is a crucial element of the overall solution. This system should adapt to any wind blade cross section along the various blade radius, avoid water puddles formation, and allow the movement of the wind blade inside the working area. The development of this solutions was segmented into two distinct technological innovations: flexible roof and sealing system. This flexible roof is composed by a set of elastic technical fabrics, whose shape is manipulated by the action of forces across the roof perimeter. The sealing system is a flexible device, that after installed across the wind blade cross section, can carry loads in both tangential and axial directions. The management of different perimeters of the wind blade cross section required the incorporation of additional interfaces such as straps, zippers, buckles, among others. These innovations and respective intellectual property is protected by a patent. The assembly of the roof and sealing systems in the inflatable habitat allows the creation of closed volume around wind turbine blade which cover the working area, the maintenance operators, and the suspended access platform. The environmental conditions on the inside are controlled using Heating, ventilation, and air conditioning (HVAC) equipment's. For that matter, it was developed a numerical model to evaluate the evolution of the environmental properties, temperature, and relative humidity, during time. A set of simulations were performed under different initial environmental conditions and equipment's list. This model will be detailed in the next section.

## A. Secondary attachment

New attachment systems were also developed to improve suspended platforms safety and attachment to the blade and to the tower these developments are now under patent preparation and will not be disclosed at this moment.

## III. ANALYSIS

### A. Inflatable structures

The internal pressure acting on a cylinder beam will induce two stress components, one in the axial direction (longitudinal stress) and other in the circumferential direction (hoop stress).

$$\sigma_h = \frac{pd}{2t}; \ \sigma_l = \frac{pd}{4t} \tag{1}$$

Where $p$ is the beam pressure, $d$ is the diameter and $t$ is the thickness. Equation (1) is used to obtain the stress state of the textile materials used in the inflatable beams. This stress state will be compared with material strength to verify if the materials can sustain the loads induce by the inflation pressure. The collapsing bending moment of the inflatable beams is another parameter that needs to be studied. The bending moment at which collapse takes place is regarded as the moment at which an increase in deflection does not result in an increase in moment. Several different expressions for the collapse moment can be found in the literature. The expressions differ in the manner they regard the material as a shell or as a membrane, or whether they concern isotropic or anisotropic material [7].

TABLE I
COLLAPSING BENDING MOMENT

| Author | Formula |
|--------|---------|
| Brazier | $\frac{2\sqrt{2}}{9} \frac{\pi E r t^2}{\sqrt{1-v^2}}$ |
| *Wood* | $\frac{2\sqrt{2}}{9} \pi E r t^2 \sqrt{\frac{1}{1-v^2} + 4\frac{p}{E}\left(\frac{r}{t}\right)^3}$ |
| *Baruch* | $\frac{2\sqrt{2}}{9} \pi E r t^2 \sqrt{\frac{E_x E_\theta}{1-v_{x\theta}v_{\theta x}}}$ |
| *Stein* | $\pi p r^3$ |
| *Zender* | $\pi p r^3 + \frac{\pi E r t^2}{2\sqrt{3(1-v^2)}}$ |
| *Seide* | $0.8\,\pi p r^3 + \pi r E_x t^2 \left(\frac{1-0.731(1-e^{-\phi})}{\sqrt{3(1-v_{x\theta}v_{\theta x})}} + \Delta_y\right)$ |
| *Wielsgosz* | $\frac{\pi}{4}\pi p r^3$ |

Where $E$ is the Young Modulus, $r$ is the radius, $v$ is the poison coefficient, $\emptyset$ is a parameter and $\Delta\gamma$ is function of the pressure. From the above presented formulation it was decided to use the Zender equation, that is semi-empirical expression deduced for membranes and isotropic materials.

The calculation of the aerodynamic load imposed in the inflatable structure was determined by (2).

$$F = \frac{1}{2} \rho V^2 S\, C_d \tag{2}$$

Where, $\rho$ is the air density, $V$ is the wind velocity, $S$ is the exposed area and $C_d$ is the drag coefficient. It was used a drag coefficient of 1. This value results from the prediction of the Reynold number and assuming a geometric shape of a cube.

To determine the loads transferred from the textile panels to the inflatable beams it was used a formulation that determines the stress state in the boundaries of a membrane fixed along all sides when subjected to a uniform pressure, see Fig.1.
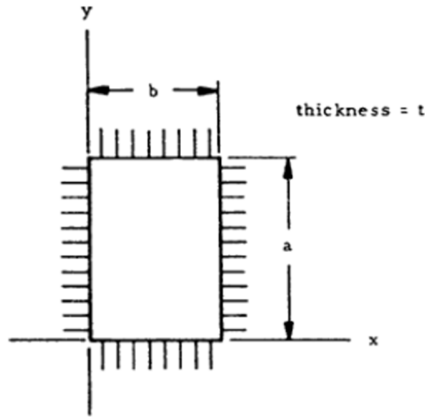


Fig. 1 Rectangular membrane fixed along all sides

The stress state in different positions of the membrane is given by (3) (4) (5):

$$x = \frac{b}{2}, y = \frac{a}{2}; \ f_x = n_2 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2}, f_y = n_2 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2} \quad (3)$$

$$x = \frac{b}{2}, y = 0; \ f_x = n_4 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2}, f_y = n_5 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2} \quad (4)$$

$$x = 0, y = \frac{a}{2}; \ f_x = n_6 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2}, f_y = n_7 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2} \quad (5)$$

The coefficients $n_2$ to $n_7$ are determined by the ration between the major and minor lengths of the membrane., see Fig.2.
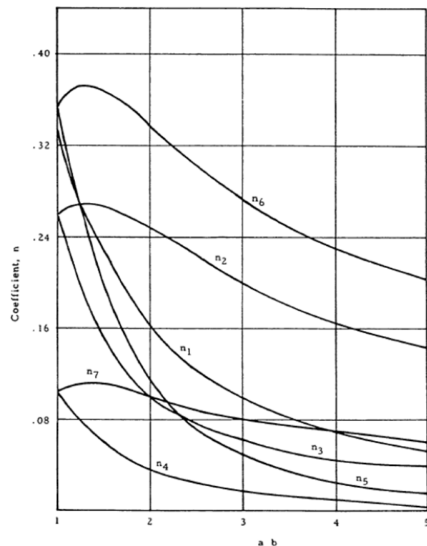


Fig. 2 Graphic used to determine the coefficients n

After obtaining the loads imposed in the inflatable beams, the shear force and bending moments diagram were determined.

From the performed analysis it was found what was best comprise between beam diameter and inflation pressure; diameter of 0.25 meters and an inflation pressure of 0.3 bar. A CAD model of the habitat core can be seen in Fig.3.
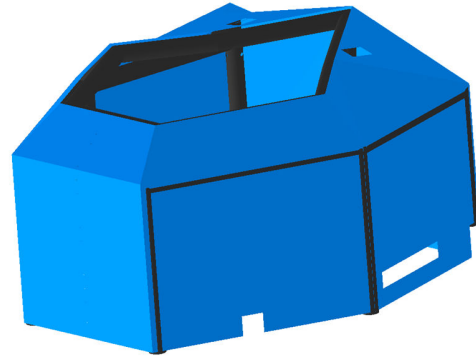


Fig. 3 Cad representation of the developed habitat

## IV. ENVIRONMENTAL CONTROL METHODOLOGY

The presence of certain environmental conditions is crucial to allow the execution of maintenance activities, particularly when composite repairs paints, etc. are needed. The in situ environmental proprieties such temperature and relative humidity need to be controlled to guarantee the effectiveness and quality of the maintenance activities. To study the evolution of these properties during time under given initial conditions, it was developed a numerical model where several phenomena are considered. At least, one fan heater and one dehumidifier will be used to manage the environmental properties inside the habitat.

The presence of water inside the habitat, resulting from its assembly during time periods of small to moderate showers, have influence in the progression of the environmental conditions. The rate of evaporated water in Kg/s is given by (6).

$$g_S = \theta \ A \ (x_s - x)/3600 \quad (6)$$

Where $\theta$ is the evaporation coefficient given by *(25+19 v)*, being *v* the air velocity above the water surface, *A* is the water surface area, $x_S$ is the maximum humidity ratio of saturated air and *x* is the humidity ratio of air.

The variation of the $x_S$ parameter with the temperature is represented in Table II.

TABLE II
VARIATION OF MAXIMUM HUMIDITY RATIO OF SATURATED AIR WITH TEMPERATURE

| Temperature *[ºC]* | $X_s$ *[$Kg_w/Kg_a$]* |
|---|---|
| 0 | 0.003767 |
| 5 | 0.005387 |
| 10 | 0.007612 |
| 15 | 0.010362 |
| 20 | 0.014659 |
| 25 | 0.019826 |
| 30 | 0.027125 |

The parameter $X$ is calculated at each time step once it is dependent on the air properties at the time.

The air absolute humidity, expressed in g/m$^3$ is function of the air temperature and relative humidity, as in (7).

$$AH = \frac{6.112 \times e^{\left(\frac{17.67\,T}{T+243.5}\right)} \times RH \times 2.1674}{273.15 + T} \tag{7}$$

The vaporization heat of the water represents the amount of energy that is removed from the system and is used to evaporate the water. This value is dependent of water temperature according to the relations expressed in Table III.

TABLE III
VARIATION OF VAPORIZATION HEAT OF WATER WITH TEMPERATURE

| Temperature [ºC] | Vaporization heat [Kj/Kg] |
|---|---|
| 2 | 2496.2 |
| 4 | 2491.4 |
| 10 | 2477.2 |
| 14 | 2467.2 |
| 18 | 2458.3 |
| 20 | 2453.5 |
| 25 | 2441.7 |
| 30 | 2429.3 |
| 34 | 2420.3 |

The heat loss to the exterior, through the walls of the habitat, is function of the temperature difference between exterior and interior and the equivalent thermal resistance. This resistance results from three different phenomena: internal convention, external convection, and conduction, and is given by (8).

$$\frac{1}{R_{total}} = \frac{1}{H_{interior}} + \frac{1}{H_{exterior}} + \frac{L}{K_{wall}} \tag{8}$$

Where $H_{interior}$ and $H_{exterior}$ are the convective coefficients, L is the wall thickness and K the thermal conductivity. The value of the convective coefficients is expressed by (9).

$$H = 12.12 - 1.16\,v + 11.6\,v^{\frac{1}{2}} \tag{9}$$

Where $v$ is the air velocity.

The process of remove water from the air is also a source of heat that needs to be included in the system. This is calculated with the same approach used for vaporization but will be introduced in the balance with opposite sign. The quantity of water removed from air, in a certain amount of time, is related with capacity of the dehumidifier. The power of the dehumidifier and fan heater will also be introduced in the final balance. Considering all the sources, the energy balance is given by (10).

$$P_{fanheater} + P_{dehumidifier} + P_{condensation} =$$
$$P_{vaporization} + P_{exterior} + P_{airheating} \tag{10}$$

The integration of this energy balance during time allows obtain the evolution of the air temperature and relative humidity. Some examples of the performed analysis are expressed in Tables IV V and VI. The total integration time was 1800 $s$.

TABLE IV
ENVIRONMENTAL CONDITIONS I

| Initial conditions | Value | Final conditions | Value |
|---|---|---|---|
| Heating Power [W] | 5000 | Temperature [ºC] | 23 |
| Temperature [ºC] | 20 | Relative humidity [%] | 68 |
| Relative Humidity [%] | 80 | | |
| Internal air velocity [m/s] | 0.5 | | |
| External air velocity [m/s] | 8 | | |
| Dehumidifier capacity [L/day] | 52 | | |

TABLE V
ENVIRONMENTAL CONDITIONS II

| Initial conditions | Value | Final conditions | Value |
|---|---|---|---|
| Heating Power [W] | 10000 | Temperature [ºC] | 22 |
| Temperature [ºC] | 18 | Relative humidity [%] | 62 |
| Relative Humidity [%] | 80 | | |
| Internal air velocity [m/s] | 0.5 | | |
| External air velocity [m/s] | 8 | | |
| Dehumidifier capacity [L/day] | 52 | | |

TABLE VI
ENVIRONMENTAL CONDITIONS III

| Initial conditions | Value | Final conditions | Value |
|---|---|---|---|
| Heating Power [W] | 15000 | Temperature [ºC] | 20 |
| Temperature [ºC] | 14 | Relative humidity [%] | 54 |
| Relative Humidity [%] | 80 | | |
| Internal air velocity [m/s] | 0.5 | | |
| External air velocity [m/s] | 8 | | |
| Dehumidifier capacity [L/day] | 52 | | |

The developed methodology can predict the evolution of the environmental properties inside the habitat under any initial circumstances, with different heating power and dehumidifier capacity.

To ensure a complete control of the interior temperature and relative humidity, a control system was developed to monitor and control both properties.

Using a PLC, we implemented a PID control loop that uses a pressure and humidity sensor and a heat source to control these variables. The loop is controlled using a PLC. First, the desired temperature and relative humidity are inserted into an HMI panel, simulated by a computational software, and, after that, the PLC compares the current values, which are measured by a temperature and humidity sensor, with the desired ones, and implements corrections to the heat output so that both variables reach the desired state. The PID control loop parameters are defined based on the type of response we want to the measured error.

## V. INFLATION CONTROL ALGORITHM

As previously stated, the developed habitat consists in an inflatable structure that allows the fast assembly of a hermetic place to repair wind turbine blades.

Once the habitat structure is large, it is important to inflate it in a certain way, to guarantee that everything works fine during

the inflation process. Besides that, during the habitat usage, several aspects can cause variations in the interior pressure of the structure, being those the permeability of the material to air or temperature variations. This is the reason why it is important not only to control the initial inflation of the habitat but also to continuously monitor the inner pressure of the structure so that it never gets out of the acceptable interval of values.

Asking the workers using the habitat to monitor this situation would not be the ideal situation, since the structure is supposed to allow them to work in better conditions and not to give them even more work than the one they already have, so the smart way to inflate the habitat structure and monitor its interior pressure is using a control system that uses information collected by sensors in order to activate or deactivate a series of electro valves and insufflation/deflation pumps that, working together, ensure that the pressure of the habitat structure is always at acceptable values. This way, the structural integrity of the habitat is never compromised.

Due to all the previous referred aspects, we developed an inflation control system that controls the initial inflation of the structure, monitors the interior pressure during the habitat usage, and controls the habitat deflation when it is packing time. The most important element of this control system is a PLC in which all the sequence of inflation and deflation where programed. Also, an algorithm to monitor and control the interior pressure of the structure was also developed.

The inflatable structure of the habitat is not built with just one inflatable, being separated into a series of independent inflatables that combined give the habitat the desired geometry. For that reason, the inflation process needs to be carefully projected and programmed.

To control the PLC and to allow the habitat users to control the inflation process, an HMI interface was also developed. This HMI interface allows the users to start the inflation and deflation processes, monitor the pressure status of each one of the parts of the inflatable structure during its use, and manually inflate or deflate separated sections when the user believes it is appropriate (the user is only able to change pressure inside the allowable interval of values). Besides all these functionalities, the HMI panel also has an emergency button that can be used to force the deflation of the structure in case any problem occurs during the habitat assembly or use.

For the particular case of inflation/deflation processes and interior pressure control, the programmed control loop was an On/Off loop. With this in mind, it will be now explained how the pressure control algorithm works.

The first stage is the insufflation. Once everything is ready, the technicians only have to press the Insufflation control button displayed on the HMI and, automatically, the inflation process begins. The first section starts to inflate until a desired pressure value is achieved (75% of the targeted pressure). After this point, another section starts to inflate, which means we have two sections inflating simultaneously at this point. This process allows technicians to control the insufflation process carefully.

All sections continue to inflate until the desired final pressure for each of them is achieved.

After all sections have been successfully inflated, the PLC continues to monitor the interior pressure of every section of the habitat. In case the pressure is lower than the minimum acceptable in any section, the inflation pump is started and the necessary electro valves are open, reinflating the desired section. With this kind of control loop, we ensure that the different structure sections always have appropriate inner pressures.

For the deflation process, the control algorithm is like the one referred for the inflation situation but with the opposite effect. This means that once the automatic deflation is activated, the deflation electro valves open, and the deflation pump starts. One relevant aspect is that the deflation process is also done section by section, which allows technicians to carefully control the deflation process. This means that only after the first section is almost totally deflated the deflation process of the second one starts, and so on until the entire structure is ready to pack.

Before testing real hardware, some simulations were performed to verify if everything from the PLC program to the designed HMI worked properly. For this purpose, three software programs were used, one to simulate the HMI, another one to simulate the PLC, working like a soft-PLC, and another one to simulate the inflatable structure. The three-software worked simultaneously and communicated using ethernet connection and Modbus TCP/IP protocol. The preformed simulations worked just like they should, with the results proving that the PLC program and the designed HMI were completely ready to be used in the real system.

Since the results obtained from the computational simulations were very promising, we performed some tests with real hardware, like pressure sensors, inflation pumps, and a real PLC. The PLC was programmed to still use the computational HMI, since it worked just like a real one and was totally reliable. These tests allowed us to verify that everything worked properly, with the inflation pump and necessary electro valves being activated every time pressure was below the desired values. The manual pressure control and emergency deflation also worked just like they should. During the performed tests, the pressure values were always displayed at the HMI, which allows technicians to check if everything is fine once in a while.

## VI. Conclusions

The main focus of this activity was to develop the cornerstone solutions for suspended blade access. From this activity resulted important intellectual property with one patent close to be granted and another one to be submitted to EPO. This is the result of an approach of developing localized new solutions to the blade repair problem. With these innovations we are now proceeding on the project of a complete system that integrates this series of innovation on a single innovative product to significantly improve the paradigm of blade repair. This project was co-founded by the national research grant P2020/Compete 2020 under the project code POCI-01-0247-

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# Effect of Inclination Angle on Productivity of a Direct Contact Membrane Distillation (Dcmd) Process

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## Abstract

A direct contact membrane distillation (DCMD) system was modeled using various angles for the membrane unit and a Reynolds number range of 500 to 2000 in this numerical analysis.
The Navier-Stokes, energy, and species transport equations were used to create a two-dimensional model. The finite volume method was used to solve the governing equations (FVM). The results showed that as the Reynolds number grows up to 1500, the heat transfer coefficient increases for all membrane angles except the $60^o$ inclination angle. Additionally, increasing the membrane angle to $90^o$ reduces the exit influence while increasing heat transfer. According to these data, a membrane with a 90o inclination angle (also known as a vertical membrane) and a Reynolds number of 2000 might have the smallest temperature differential. Similarly, decreasing the inclination angle of the membrane keeps the temperature difference constant between Reynolds numbers 1000 and 2000; however, between Reynolds numbers 500 and 1000, the temperature difference decreases dramatically.

***Keywords****: Direct contact membrane distillation; membrane inclination angle; heat and mass transfer; Reynolds number.*

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# Study Motivations and Reasons for the Tendency of Iranian Youth to Bet Sites: Case Study of Bet Forward Site

Nastaran Rafiei

***Abstract*—** Today, many innovations in the field of entertainment have been invented due to the development of digital space and the expansion of virtual world platforms. One of these pastimes is playing on betting sites, which has gained a lot of fans among Iranian teenagers and youth. The dramatic expansion of this site led me to seek out, target and select users to register and operate on betting sites. These are serious questions that motivate users to spend time on betting sites? Are users satisfied with their experience and performance? And is it fun to have fun with betting and predicting games? I also studied the reasons that lead to playing on such sites. In the present study, the qualitative research method is participatory observation and semi-structured interview, and a total of 12 users of the Bet Forward betting site were interviewed.The research sampling was done based on the available method and snowball technique and the collected data were analyzed by thematic method. The findings of this study have been analyzed and sociologically interpreted with theories of use and satisfaction, active audience, entertainment and philosophical views of leisure. Preliminary summary of the results shows that economic needs and environmental impacts are the most important factors in the tendency of young people and adolescents to earn money through betting sites and the weakness of the country is low monitoring, lack of monitoring in the field of legislation and weakness. In virtual field education.

***Keywords*—** betting site,electronic casino,leisure,online gaming.

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# The Missile Attack Rigid Inflatable Boat Project: A Vision of Naval Superiority in the Actual Sea Power

Diego Abbo

***Abstract***— The M.A.R. project involves the design and subsequent construction of naval units (RIBs - Rigid inflatable boats) missiles and torpedoes armed with integrated logistics and operational support systems. All this, in compliance with the priority of naval superiority, would constitute a combat system, with the lowest existing cost/effectiveness ratio, addressed both to the defense of the territories of the coastal State to the projection of power in more remote geographical areas.

These are small, fast armed units (rubber dinghies - RIB is an acronym that stands for Rigid Inflatable Boat with a length of 50/60 feet (15/20 meters) in the three variants of naval warfare (anti-ship, air defense, and anti-submarine) which have the following operational characteristics other than being virtually unsinkable:

1. Possibility to stay continuously at sea 10/15 days with refueling capacity at sea;

2. The crew of 3 or 4 people maximum depending on the type of mission;

3. Armed with missile systems with anti-aircraft and anti-aircraft capabilities to completely neutralize the opponent according to a study on the potential adversary's vulnerabilities;

4. The secondary weapon system consists on small-caliber conventional artillery (maximum 30 mm without fuse)

5. Ability to manage UAVs (aerial drones) or UNVs (maritime drones)

6. Ability on command and control management of vessels and aircraft used in the same mission.

7. Ability to perform multi-purpose missions from full conflict to peacekeeping and the fight against piracy.

8. Possibility of configuration with torpedoes for antisubmarine hunting (modified version compared to the original ones mentioned above);

9. Low costs if compared to the larger units that must carry out the aforementioned similar missions.

10.  Greater sustainability in the duration of single missions in terms of costs dedicated by the Political Authority

The integrated logistic support system is considered as the dual possibility of:

• Plan the reconversion of existing ships, both military and merchant ships, to have the role of mother ship for the embarkation of the MAR and their redeployment in the area of operations;

• Design floating platforms with autonomous energy capacity (wind, photovoltaic) that can be refueling points, electromagnetic and acoustic emission stations aimed at information on combat operations;

The integrated operational support system is considered as the possibility of planning and management aimed at controlling the electromagnetic space in the specific operating theater. It is therefore a question of being able to manage, in real-time, all communications coming from surface stations and from satellites according to a complex structure designed and implemented.

Finally, it should be underlined the possibility of "multiple uses" of the same adapted vehicles, as humanitarian employment, as hydro-ambulances, means of control of fishing operations, high seas police.

***Keywords***— metrics of naval power, neutralization offensive enemy' capacity, safe routes communication for friend ships, strategic concentration of naval forces in a sensitive area.

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# Liposomal Antihelmintics in Parasitology

Nina Ivanova

***Abstract***— More than one third of the population and animals are infected with parasitic helminths. It is especially difficult to cure the larval forms of parasites. The larvae of Hymenolepis nana invade the villi of the intestinal mucosa. Toxocara larvae can live in the liver, heart, lungs, brain, eyes, and pancreas. Commercial antiparasitic drugs cannot guarantee a 100% cure after a single course of treatment, because parasite larvae invade the villi of the intestinal mucosa and the anthelmintics do not reach and kill cestode larvae. The aim of this work was to conduct a study of liposomal antihelminthics on the laboratory animals under the certification received from the Committee on Bioethics and Deontology. It has been checked: 1) anthelmintic activity of the liposomal form of fenasal in experimental hymenolepidosis of white mice (larval stage - Hymenolepis nana). 2) anthelmintic activity of the liposomal form of albendazole in experimental toxocariasis of white mice (in the lungs at the stage of larval migration). Since some helminths cause hemolysis of erythrocytes as we used a mixture of polar lipids developed by us with antihemolytic activity to obtain liposomes Fenasal and albendazole were included in the liposome membrane in the ratio of anthelmintic: lipids 1:10. . The average size of liposomes was 180 nm, and the concentration of lipids in liposomes was 1%. The researches were carried out on white male mice who were infected with Hymenolepis Nana invasional eggs in a peroral way with a doze of 100 eggs per animal. On the 5th day after infection, a liposomal fenasal and commercial fenasal were administered orally for comparison. The animals were observed for 15 days. Before the introduction of liposomes and on the 3rd, 5th, 15th day after the administration of the drug, studies were carried out on the presence of helminths in the organs of animals. The liposomal fenasal, when administered orally, had an anthelmintic effect on Hymenolepis Nana cysticercoids at a dose of 25 mg/kg. The percentage of efficiency was 90.06, 91.36 96.85% on days 3, 5, 15, respectively. For comparison, the commercial activity was at a dose of 200 mg/ml, which is 8 times higher than the dose of liposomal fenasal. To evaluate the anthelmintic effect of the liposomal form of albendazole in experimental toxocariasis of white mice (toxascaris in the lungs at the stage of larval migration), studies were also carried out on white mice. The animals were infected with invasive eggs of Toxocara canis, orally, at a dose of 100 eggs per animal. On the 5th day after infection, the liposomal albendazole was administered orally. The efficacy of the study dosage form was determined by counting Larva mirgans larvae in the lungs. The results obtained showed that the liposomal albendazole had the greatest anthelmintic effect on Toxocara larvae at a dose of 2.0 mg/kg, which was 3.75 times less than the therapeutic one. At the same time, the percentage of efficiency was 93.75% on the 3rd day, and 98.66% on the 5th day.

***Keywords***— hymenolepis, Toxocara, larvae, liposomes.

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# Quality of Life and Renal Biomarkers in Feline Chronic Kidney Disease

Bárbara Durão, Pedro Almeida, David Ramilo, André Meneses, Rute Canejo-Teixeira

***Abstract*—** The importance of quality of life (QoL) assessment in veterinary medicine is an integral part of patient care. This is especially true in cases of chronic diseases, such as chronic kidney disease (CKD), where the ever more advanced treatment options prolong the patient's life. Whether this prolongment of life comes with an acceptable quality of life remains has been called into question. The aim of this study was to evaluate the relationship between CKD disease biomarkers and QoL in cats. Thirty-seven cats diagnosed with CKD and with no known concurrent illness were enrolled in an observational study. Through the course of several evaluations, renal biomarkers were assessed in blood and urine samples, and owners retrospectively described their cat's quality of life using a validated instrument for this disease. Correlations between QoL scores (AWIS) and the biomarkers were assessed using Spearman's rank test. Statistical significance was set at p-value < 0.05, and every serial sample was considered independent. Thirty-seven cats met the inclusion criteria, and all owners completed the questionnaire every time their pet was evaluated, giving a total of eighty-four questionnaires, and the average-weighted-impact-score was −0.5. Results showed there was a statistically significant correlation between the quality of life and most of 17 the studied biomarkers and confirmed that CKD has a negative impact on QoL in cats especially due to the management of the disease and secondary appetite disorders. To our knowledge, this is the attempt to assess the correlation between renal biomarkers and QoL in cats. Our results reveal a strong potential of this type of approach in clinical management, mainly in situations where it is not possible to measure biomarkers. Whilst health-related QoL is a reliable predictor of mortality and morbidity in humans; our findings can help improve the clinical practice in cats with CKD.

***Keywords*—** chronic kidney disease, biomarkers, quality of life, feline.

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# Nisin Production by a Mixed Culture of *Lactoccocus Lactis Subsp.Lactis* and *Yarrowia Lipolytica* in Molasses Base Medium

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## Abstract

Nisin is a commercial bactriocin that is used as a food preservative and produced by *Lactcoccus lactis* subsp. *lactis*. Nisin production through co-culture fermentation can be performed for increasing nisin quantities. Since lactate accumulation in fermentation medium can prevent *L. lactis* growth and therefore reduce nisin production, simultaneous culture of microorganisms can enhance *L. lactis* growth by reduction in the amount of lactic acid. In this study, conducted coculture of L.lactis subsp. lactis and the yeast *Yarrowia lipolytica*. Both strains are cultured in molasses base medium that is mainly constructed of sucrose. *Y. lipolytica* is not able to use sucrose as carbon source but able to consume lactate as and decrease lactic acid in medium. So, Lactic acid consumption can increase pH value and stimulus *L. lactis* growth. The results showed the mixed culture increased *L. lactis* growth 6 times higher than that of pure culture and could enhance nisin activity up to 40%.

**Keywords:** Nisin, Co-culture Fermentation, Molasses base medium, Lactate consumption

## Introduction

Nisin is one of the most important members of bacteriocin families. This peptide is located in bacteriocin group 1 or lantibiotics. Nisin consists of 34 amino acids including modified amino acids such as lanthionine and batamethyl lanthionine (Field, Begley et al. 2012). Nisin molecular weight is 3354 Dalton and produced by *Lactococcus lactis* strain sub sp. *lactis*. Nisin has antibacterial effects against gram positive bacteria and their spore forms, and also is used as a food preservative (Kim 1997). Nisin is approved in more than 50 countries as food additive (Lv, Cong et al. 2004). This mode of action has been studied well over the times. Nisin Molecule adjoins to lipid II and constructed pore in membrane cell. The pores cause losing ions and disrupting of pH balances and death of microorganisms(González-Toledo, Domínguez-Domínguez et al. 2010).

Nisin exists in two forms of nisin A and nisin Z which differs in 27 position of their structures(Mulders, Boerrigter et al. 1991). Nisin has been commercialized as food additives in various food industries such as dairy and meat products. Besides routine factors regarded in nisin production including effect of carbon and nitrogen sources or temperature, the inhibition effects of by-metabolite produced by *L. lactis* in the medium culture (Liu, Zheng et al. 2010). Lactic acid bacteria (LAB) produce several antibacterial compounds like lactic acid, formic acid and bacteriocins. These bacteria are used as starter culture in food industry(Leroy and De Vuyst 2004). Lactic acid produced by LAB, is applied in different industries such as biopolymer construction, food preservatives, food flavors and pharmaceutical compounds. Approximately, 80% of total lactic acid production all around the world is related to the production by microorganisms in fermentation process. The reason is that the production of lactic acid through biological processes causes that only one of the two D and L isomers be produced, while the production through chemical methods gives a racemic mixture of both isomers(Hofvendahl and Hahn–Hägerdal 2000). In spite the fact that lactic acid production by *Lactococcus lactis* is commercially beneficial, Nisin production by *L. lactis* is negatively affected by lactic acid in fermentation process. By increasing lactic acid accumulation in the media, bacterial growth and consequently nisin production will be reduced. There are many ways for decreasing the lactic acid in medium such as extraction by solvents or alkali neutralization. However, using solvent extractions make the medium unusable for food additives (Shimizu, Mizuguchi et al. 1999). Besides the mentioned separation approaches of lactic acid from the cultivation system, co-culture fermentation of microorganisms is one way to reduce the lactic acid. Since sucrose is one of the best carbon sources for nisin production by *L. lactis* (Parente and Ricciardi 1999), selected microorganisms should not use sucrose as carbon source, and instead, they should use lactid acid. *Yarrowia lipolytica* is a potent yeast to be used for simultaneous culture with L.lactis owing to the fact that *Y. lipolytica* is isolated naturally from cheese and dairy products (Nicaud 2012). So regarding to the isolating source it is very similar to *L. lactis. Y. lipolytica* shows no ability to use sucrose because of the lacking of sucrose cleaving enzymes, but there are abilities for using fatty acids, alkanes and organic acids as carbon sources (Coelho, Amaral et al. 2010). ammonium with lactic acid can be consumed by this yeast, resulting in increasing pH (Mansour, Beckerich et al. 2008), *Y. lipolytica* is able to growth in acidic pH as well(Coelho, Amaral et al. 2010).The aim of this study is The growth increasing *L. lactis* growth by decreasing levels of lactic acid and enhancing of pH in the medium, as well as increased rate of nisin production by *Lactococcus lactis* .

## Materials and methods

### Microorganisms and Media

*L. lactis* sub sp.*lactis* (UTMC 106) and *Micrococcus luteus* (UTMC) were used as nisin producing and nisin sensitive strain, respectively. *Y. lipolytica*(UTMC) was used for co-culture fermentatation with *L. lactis*. The composition of different media were used as follows. Medium I contained 10gr/l sucrose, 10gr/l yeast extract, 10gr/l peptone, 10gr/l $K_2HPO_4$, 2gr/l NaCl, 0.2gr/l $MgSO_4$, was used for seed culture of *L. lactis*. Medium II contained 10gr/l yeast extract, 20gr/l peptone, 30ml/l glycerol, was used for seed culture of *Y. lipolytica*. MediumIII contained, 80gr/l molasses, 20gr/l soybean, 10gr/l $K_2HPO_4$, 2gr/l NaCl, 0.2 gr/l $MgSO_4$, was used for co-culture fermentation of *L. lactis* and *Y. lipolytica*. MediumIV, BHI (Brain Heart Infusion) medium

contained 1% tween 20 and 0.75 agar for agar diffusion method in order to nisin concentration bioassay. Medium V contained, 5gr/l maltose, 5gr/l yeast extract, 5gr/l peptone, 5mg/l cyclohyximide, 15gr/l agar, that was used for determination of CFU (Cloning Forming Unit) as specific medium for *L. lactis*. Medium VI contained, 5gr/l glucose, 5gr/l yeast extract, 5gr/l peptone and 5mg/l streptomycin, 15gr/l agar, used for CFU determination of *Y. lipolytica* as specific medium for yeast.

**Cultivation method**

In order to increase the amount of cells before the main co-culture fermentation, seed cultures of *L. lactis* and *Y. lipolytica* were grown in 100-mL Erlenmeyer flasks and incubated at 100 rpm and 30 C° for 12 h and 160 rpm and 30C° for 24 h, respectively. 8% v/v from each seed cultures was inoculated in to main fermentation medium. Co-culture fermentation was performed in 1-L Erlenmeyer flask and placed on an orbital shaker at 100rpm and 30C° for 40 h.

**Analyses**

Response surface methodology was designed for carbon and nitrogen sources optimization. Optical density (OD) of the seed cultures were measured using spectrophotometer at 600 nm. For determining the *L. lactis* and *Y. lipolytica* cell concentrations, CFU (Cloning Forming Unit) counting was conducted. For lactic acid dosage in medium, was estimated with titration assay. Sucrose consumption was analyzed by Phenol sulfuric acid method and nisin production was quantified by reverse-phase high performance liquid chromatography (RP-HPLC).

**Optimization of molasses base medium culture**

For appraisal of co-culture fermentation at first, the medium of *L. lactis* was optimized for increasing growth. In this medium, three factors of sugar beet molasses, soybean meal and the volume of Erlenmeyer flask of medium culture were optimized. Box-Behnken design is a type of response surface design was used for optimization of these factors.

**CFU evaluation**

CFU counting approach was applied for determination of *L. lactis* growth rate . First, serial dilution was performed from medium culture and spreaded on medium V and VI for *L. lactis* and *Y. lipolytica*. Appeared colonies were counted after 24 h.

**Lactic acid determination**

Lactic acid was measured by titration with NaOH 0.1M and phenolphthalein as the indicator(Wasewar, Heesink et al. 2002). The samples were provided each 3h for 40h in single and co-culture fermentation to calculate the amount of lactic acid.

**Nisin bioassay**

Antibacterial activity of the nisin was assayed by agar diffusion method (Pongtharangkul and Demirci 2004) In BHI medium plus 0.75% agar and 1% Tween 20 and the medium was boiled and then sterilized. When temperature reached to about 40 $C°$, the medium was inoculated with 1% of a 24-h culture of *M. luteus* which was incubated at 37 $C°$ with an absorbance (A) of 1.7 at 600 nm. Sterile Petri dishes were filled with 25 mL of the inoculated bioassay medium, and after solidification, wells were bored. Subsequently 50µl of each fermentation broth was poured into each well. The Petri dishes were incubated at 4 $C°$ for 24 h and then incubated at 37 $C°$ for 24 h and inhibition zones were measured. In order to construct standard curve, a stock solution of nisin (1,000 IU/mL) was prepared by dissolving 0.025 g of commercial nisin 1000 IU/g (Handary company) in 25mL sterile diluent solution of 0.02 M HCl. Standard nisin solutions in the range of 100, 200, 300, 400 and 500 IU/mL were prepared using 0.02 M HCl. The standard curve was prepared using the diameters of inhibition zones against the log 10 of nisin concentrations.

**Sucrose analysis by Phenol Sulfuric acid method**

Sucrose of beet molasses was measured by Phenol Sulfuric acid method(Dubois, Gilles et al. 1956). Since sugar beet molasses consist more than 50% sucrose, rate of consumption in single and co-culture fermentation during 24 h shows bacterium growth in fermentation broth. In Phenol sulfuric acid method first, different concentration of sucrose including 40, 80, 120, 160 and 200 $\mu g / ml$ are prepared for drawing standard curve. Medium culture was sampled each 3h to determine sucrose concentration in both single and co-culture fermentation. 0.2 ml phenol 5% followed by 1ml concentrated sulfuric acid were added to the samples and OD was measured at 490nm.

**Nisin quantification by High Performance Liquid Chromatography (HPLC)**

Nisin was purified from *L. lactis* medium culture after 24 h incubation. The cells were harvested by centrifugation at 12000×g, 4 $C°$ for 30 min. The proteins were precipitated by 80% ammonium sulfate at 4 $C°$ for 24 h and centrifuged at 17400×g for 50 min. The pellet was dissolved in 10 ml of 3 M urea and loaded on C18 Cartridge column. The Cartridge was washed by 10%, 40% and 80% acetonitrile(Ivanova, Kabadjova et al. 2000). The collected fractions were assayed for nisin bioactivity with agar well diffusion method. The suspected fraction was subjected to final nisin analysis by RP-HPLC. The sample was eluted in following mobile phase: 13% water and 87%acetonitrile in isocratic mode and peptides were detected at 220 nm, at a flow rate 1ml/min.

**Batch culture models**

Kinetic model for cell growth by Monod equation for exponential phase of L.lactis

$$\mu = \frac{\mu_m . S}{K_S + S}$$

$\mu$ = specific cell growth rate (hr$^{-1}$)

$\mu_m$ = maximum specific cell growth rate (hr$^{-1}$)

$S$ = substrate concentration (g/L)

$K_S$ = Saturation constant (g/L) = $S$ when $\mu$ = 1/2 $\mu_m$.

$$\mu = \frac{1}{X}\frac{dX}{dt} = \frac{\mu_m . S}{K_S + S}$$

$$X - X_0 = Y_{X/S}(S_0 - S)$$

$Y_{X/S}$ = cell mass yield

$X_0$, $S_0$ = initial concentration of cells and substrate

$$\frac{dX}{dt} = \frac{\mu_m(S_0 Y_{X/S} + X_0 - X)}{(K_S Y_{X/S} + S_0 Y_{X/S} + X_0 - X)}X \quad ; \text{at} \quad t = 0, X = X_0$$

$$\frac{(K_S Y_{X/S} + S_0 Y_{X/S} + X_0)}{(S_0 Y_{X/S} + X_0)}\ln\left(\frac{X}{X_0}\right) - \frac{K_S Y_{X/S}}{(S_0 Y_{X/S} + X_0)}\ln\left\{(S_0 Y_{X/S} + X_0 - X)S_0 Y_{X/S}\right\} = \mu_m t$$

**Result**

**Optimization of medium culture by Response Surface Methodology (RSM)-Box Behnken**

The result of response surface design shows the optimum growth rate of producer strain was achieved in 72 g/l, 20 g/l soybean and 3.5 ratio for concentration of sugar beet molasses, soybean and flask volume ratio to medium culture (Fig. 1). This highest level of nisin production was used for mixed culture fermentation of *L. lactis* and *Y. lipolytica*.

**Determination of *L. lactis* growth in co-culture fermentation**

In CFU counting method $1.2 \times 10^9$ CFU/ml for co-culture and $2 \times 10^8$ CFU/ml for pure culture of *L. lactis* were determined Indicating that cell number in co-culture fermentation is 6 times higher than pure culture. Also $9 \times 10^7$ CFU/ml was counted for *Y. lipolytica* after 24 h. (Fig. 2)

**Acid lactic and pH analysis in medium culture**

Since *L. lactis* is a homo-fermentative bacterium, lactic acid is the major product of fermentation which leads to pH variation in culture media. First, *Y. lipolytica* growth ability in acidic pH was studied. Therefore, the pH of molasses base medium was adjusted to 3 using acid lactic and incubated at $30\,C°$ for 24 h. The OD of 1.9 at 600 nm observed after incubation revealed that *Y. lipolytica* has a significant growth ability in acidic pH. Since *Y. lipolytica* caused no change in initial medium pH. It can be concluded that variation of pH in co-culture fermentation is considerably related to *L. lactis* growth. Titration assays showed that lactic acid concentration in beginning hours of co-culture fermentation was higher than pure culture; however, the concentration decreased in final hours (Fig. 3). As a result, in final hours of fermentation time lactate accumulation caused growth inhibition but in co-culture fermentation the bacterium growth was maintaining with lactate consumption by *Y. lipolytica.*

**Sucrose analysis by phenol sulfuric acid method**

Sucrose determination was performed for comparison of sucrose consumption in pure and co-culture fermentation broth. At first, *Y. lipolytica* was cultured in a medium with sucrose as only carbon source for investigating its growth ability. Considering that *Y. lipolytica* showed no growth in sucrose containing media in contrast to co-culture which consume the sugar during incubation the observed changes in sucrose concentration can be referred to *L. lactis*. Following phenol sulfuric acid method in co-culture fermentation, the speed of sucrose concentration decreased was higher in comparison to that of *L. lactis* pure culture. In addition, sucrose consumption was continued until 40th h. Also, sucrose consumption was stopped at 18th h in *L. lactis* pure culture (Fig. 4).

**Nisin analysis by RP-HPLC**

Nisin concentration in all collected co-culture samples were higher than that of in pure culture by 25 to 40% (Fig. 5). The bacteriocin was purified after 24 h from fermentation medium. Approximately 70% recovery was achieved by ammonium sulfate precipitation. After nisin concentration by C18 Cartridge and eluting by 10% acetonitrile, nisin activity was increased to 10000 IU/ml and chromatograms were detected on C18 RP-HPLC (Fig.6)

**Discussion**

In simultaneous cultivation system design, medium components such as the carbon source should be properly determined. Not only the other microorganism should not use the main carbon source, but also it could be able to use lactic acid as carbon source for growth and should not be harmful

for *L. lactis* (Spencer and de Spencer 2001). Co-culture fermentation of *L. lactis* with *saccharomyces* in Whey (Liu, Hu et al. 2006) } and *kluyveromyces* in maltose base media(Shimizu, Mizuguchi et al. 1999) have been studied before. In this study a new approach for nisin production by L.lactis in co-culture fermentation by industrial medium is presented. Nowadays carbohydrate based media like molasses are considered as affordable alternatives of dairy byproducts for nisin production. In this study nisin concentration was enhanced from 90 mg/l in pure culture to 150 mg/l in co-culture of *L.lactis* with *Y.lipolytica*. In pure culture system after 15h the rate of productivity and cell growth were decreased drastically due to lactate accumulation. On the other hand, in co-colture fermentation of *L. lactis* and *Y. lipolityca*, the growth of producer strain and nisin production are maintained by lactic acid consumption by *Y. lipolytica* even after 18th h. This theory is not explicable for early stage of fermentation due to even in beginning hours, in spite of lack of acid lactic *L. lactis* growth and nisin production were increased in comparison to its pure culture. The cell growth stimulation by *Y. lipolitica* needs to be studied by further investigations. In comparison to other co-culture fermentation systems for nisin production this approach has some advantages such as source of isolation of microorganisms and carbohydrate base medium as culture medium and rate of productivity. The current co-culture approach utilizes this commercial benefit for yield enhancement. This study shows co-culture fermentation of producer strain with *Y. lipolitica* can be impressive in fed-batch and continuous culture since lactate accumulation and pH control are important during fermentation time.

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**Figure captions**

**Fig.1** Response surface design and contours of the Molasses and Soybean obtained by RSM model.

**Fig.2** Cell concentration counting by CFU method for pure and co-culture fermentation of *L. lactis*.

**Fig.3** Lactate concentration and acidity profile in pure and co-culture medium.

**Fig.4** Comparison of sucrose consumption rate by *L. lactis* in pure and mixed culture.

**Fig.5** Nisin productivity analysis by RP-HPLC and variation in pure and simultaneous culture.

**Fig.6** RP-HPLC chromatogram of nisin fraction by RP-18 column.
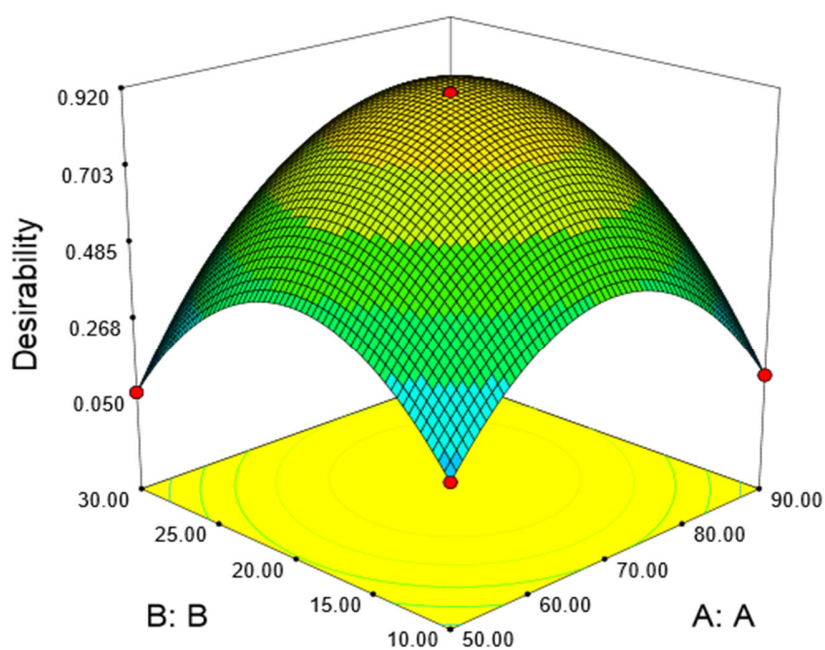


Fig.1
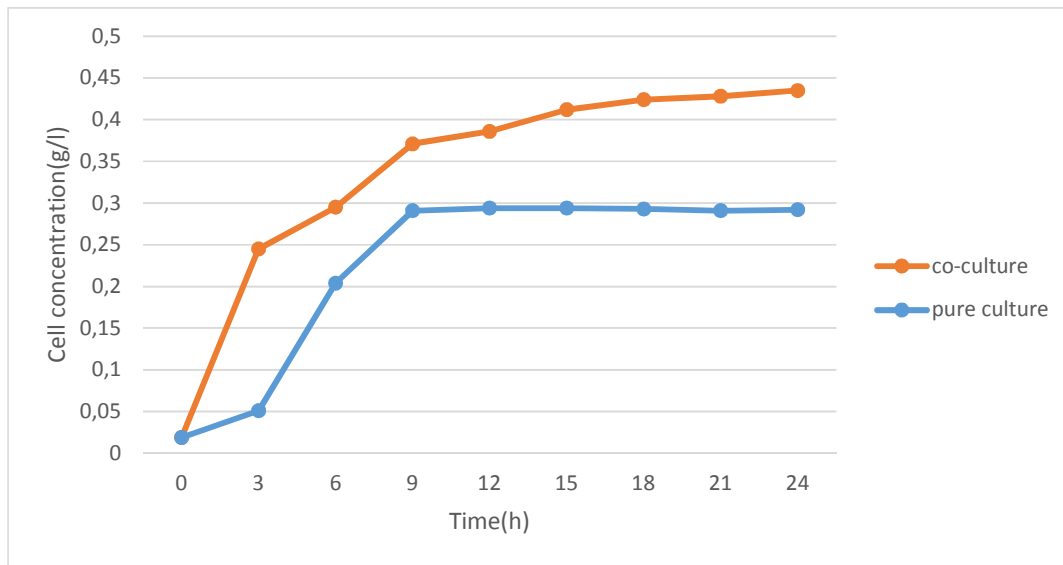
Fig.2
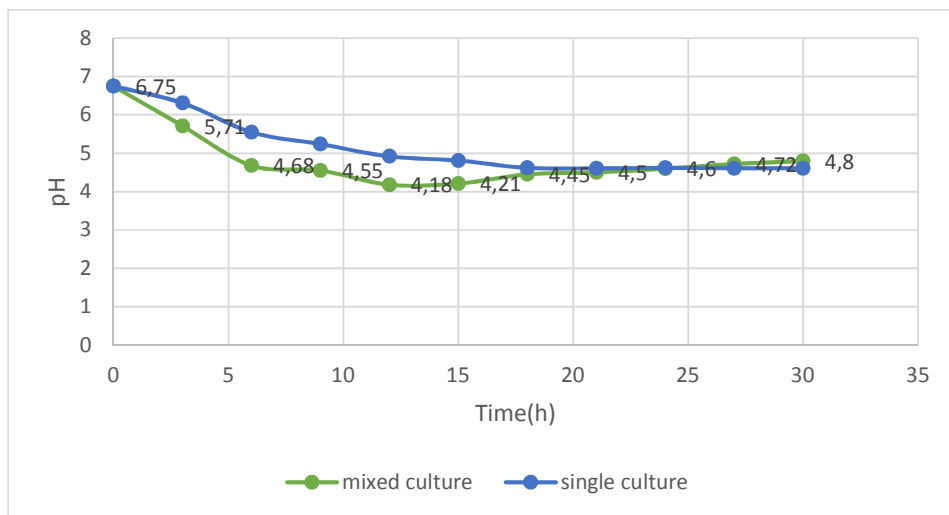


Fig.3
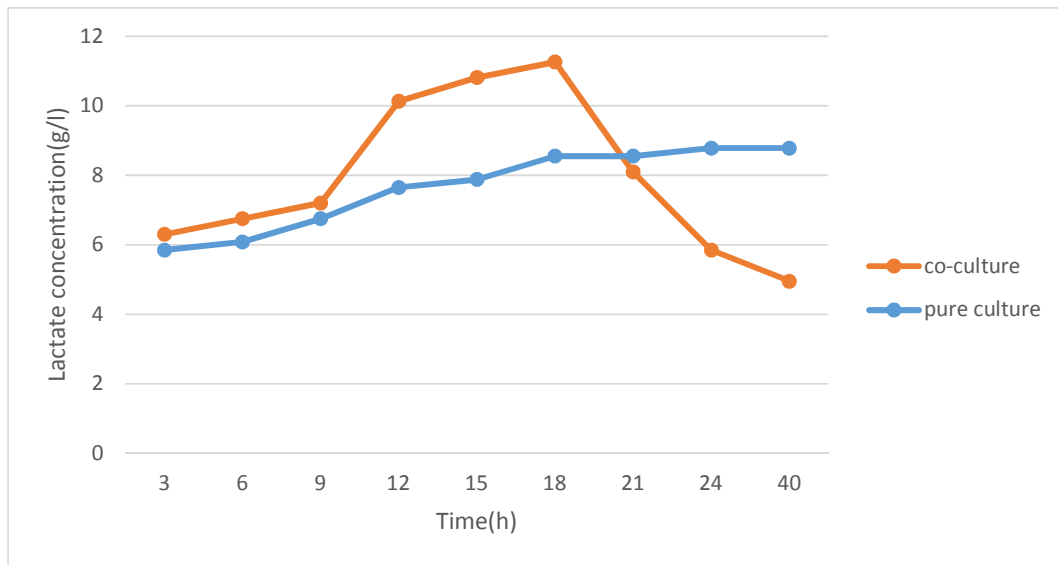
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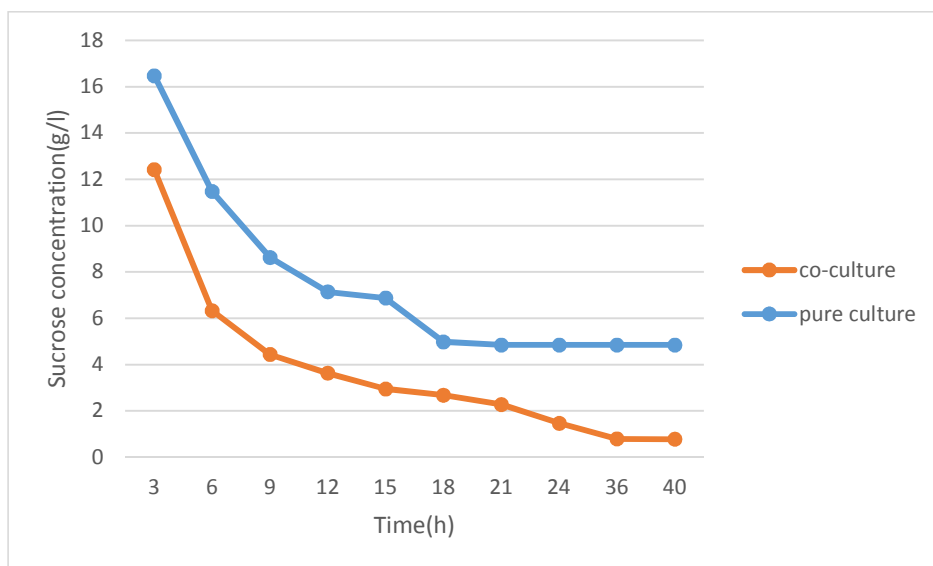


Fig.4
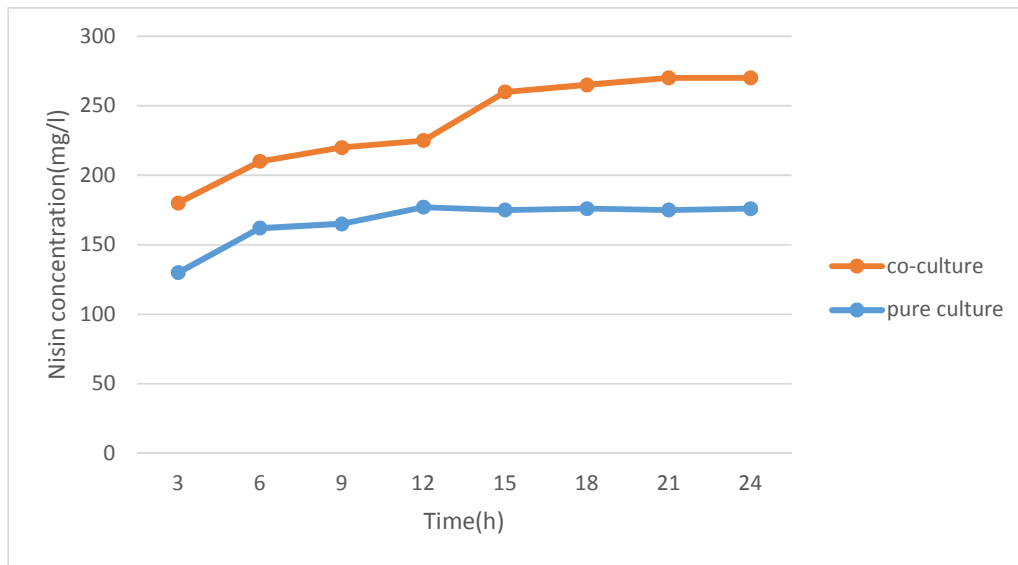
Fig.5
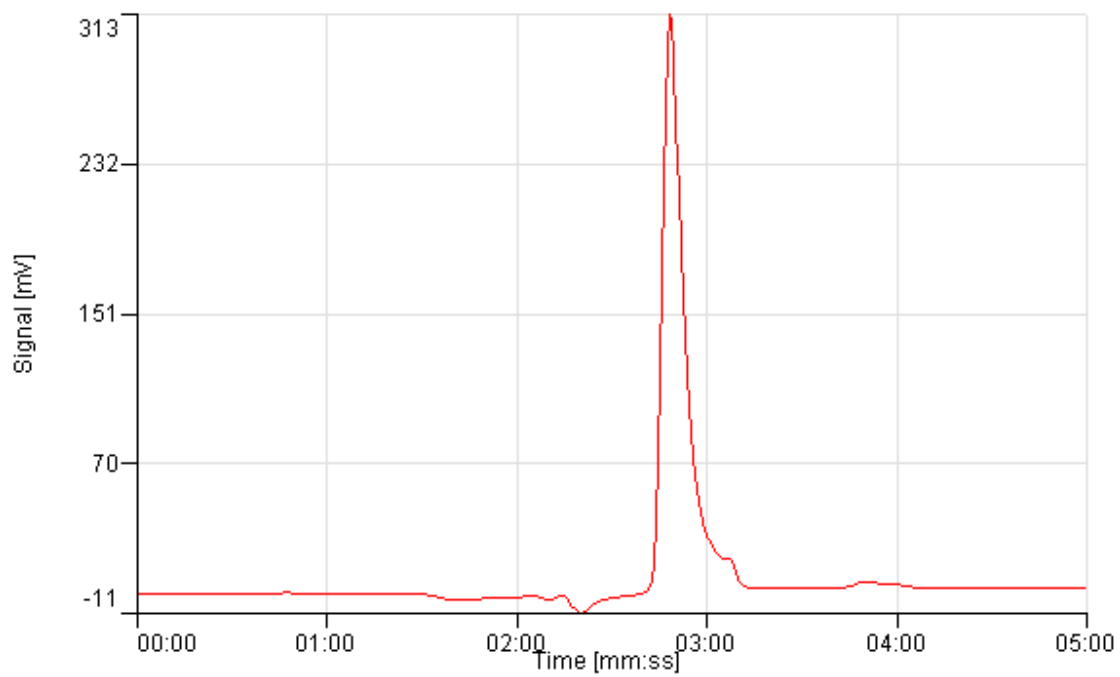


Fig.6

**Table 1** growth kinetic parameters for batch culture fermentation

| Fermentation time $(h)$ | $S$ $(g.l^{-1})$ | $X$ $(g.l^{-1})$ | $\dfrac{dX}{dt}$ $(g.l^{-1}.h^{-1})$ | $\mu$ $[(1/X)(dX/dt)](h^{-1})$ | $\dfrac{1}{\mu}$ $(h^{-1})$ | $\dfrac{1}{S}$ $(1.g^{-1})$ |
|---|---|---|---|---|---|---|
| 3 | 16.47 | 0.051 | | | | |
|   | 12.41 | 0.245 | | | | |
| 6 | 11.47 | 0.204 | | | | |
|   | 6.33 | 0.295 | | | | |
| 9 | 8.63 | 0.291 | | | | |
|   | 4.44 | 0.371 | | | | |
| 12 | 7.14 | 0.294 | | | | |
|    | 3.63 | 0.386 | | | | |
| 15 | 6.87 | 0.294 | | | | |
|    | 2.95 | 0.386 | | | | |
| 18 | 4.98 | 0.293 | | | | |
|    | 2.28 | 0.424 | | | | |
| 21 | 4.85 | 0.291 | | | | |
|    | 1.47 | 0.428 | | | | |
| 24 | 4.85 | 0.292 | | | | |
|    | 0.79 | 0.435 | | | | |
|    |      |       | | | | |

# Information Pollution: Exploratory Analysis of Subs-Saharan African Media's Capabilities to Combat Misinformation and Disinformation

M. J. Mustapha, F. J., S. O. Agyei, R. A. Adebiyi, M. I. Lasisi

*Abstract*— The role of information in societal development and growth cannot be over-emphasized. It has remained an age-long strategy to adopt the information flow to make an egalitarian society. The same has become a tool for throwing society into chaos and anarchy. It has been adopted as a weapon of war and a veritable instrument of psychological warfare with a variety of uses. That is why some scholars posit that information could be deployed as a weapon to wreak "Mass Destruction" or promote "Mass Development". When used as a tool for destruction, the effect on society is like an atomic bomb which when it is released, it pollutes the air and suffocates the people. Technological advancement has further exposed the latent power of information and many societies seem to be overwhelmed by its negative effect. While information remains one of the bedrocks of democracy, the information ecosystem across the world is currently facing a more difficult battle than ever before due to information pluralism and technological advancement. The more the agents involved try to combat its menace, the difficult and complex it is proving to be curbed. In a region like Africa with dangling democracy enfolds with complexities of multi-

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religion, multi-cultures, inter-tribes, ongoing issues that are yet to be resolved, it is important to pay critical attention to the case of information disorder and find appropriate ways to curb or mitigate its effects. The media, being the middleman in the distribution of information, needs to build capacities and capabilities to separate the whiff of misinformation and disinformation from the grains of truthful data. From quasi-statistical senses, it has been observed that the efforts aimed at fighting information pollution have not considered the built resilience of media organisations against this disorder. Apparently, the efforts, resources and technologies adopted for the conception, production and spread of information pollution are much more sophisticated than approaches to suppress and even reduce its effects on society. Thus, this study seeks to interrogate the phenomenon of information pollution and the capabilities of select media organisations in Sub-Saharan Africa. In doing this, the following questions are probed; what are the media actions to curb the menace of information pollution? Which of these actions are working and how effective are they? And which of the actions are not working and why they are not working? Adopting quantitative and qualitative approaches and anchored on the Dynamic Capability Theory, the study aims at digging up insights to further understand the complexities of information pollution, media capabilities and strategic resources for managing misinformation and disinformation in the region. The quantitative approach involves survey and the use of questionnaires to get data from journalists on their understanding of misinformation/disinformation and their capabilities to gate-keep. Case Analysis of select media and content analysis of their strategic resources to manage misinformation and disinformation is adopted in the study while the qualitative approach will involve In-depth Interview to have a more robust analysis is also considered. The study is critical in the fight of information pollution for a number of reasons. One, it is a novel attempt to document the level of media capabilities to fight the phenomenon of information disorder. Two, the study will enable the region to have a clear understanding of the capabilities of existing media organizations to combat misinformation and disinformation in the countries that make up the region. Recommendations emanating from the study could be used to initiate, intensify or review existing approaches to combat the menace of information pollution in the region.

*Keywords*— Disinformation, Information Pollution, Misinformation, Media Capabilities, Sub-Saharan Africa.

# Bioethical Standards as a Tool for the Improvement of Human Relations Toward Health, Animals, and Plants: The Example of Three Croatian Mediterranean Local Communities

Toni Buterin, Robert Doričić

*Abstract*— Mainstream bioethics, narrowed down mainly to human medicine and research, can hardly be expected to efficiently face modern challenges related to environmental issues. Departing from the interpretation of "European Bioethics" as a discipline considering ethical duties not only toward fellow humans, but to all living beings, this paper presents the results of a study conducted in three communities in Croatian Northern Adriatic region, selected for their recent experience of ecological threats (Labin – thermo-electric power plant; Bakar – cokery), or representing a highly-valuable and vulnerable natural insular pocket (Mali Lošinj – health tourism, dolphin wildlife refuge, fragrant gardens programme, etc.). After targeted workshops and interviews had been organised in those communities, the results of the obtained insights were combined with experts' opinion and a list of around hundred "bioethical standards" was formed. "Bioethical standards" represent a set of principles and measures of the correct attitude of people towards their own health, animals, plants, and the eco-system as a whole. "Bioethical standards" charter might improve the level of local community environmental consciousness, and provide direct guidance for its sustainable development (including its tourism-advertising ace card). The present paper discusses the standards' potential benefits and some implementational risks.

*Keywords*— Bioethical standards, Croatia, European bioethics, Local communities.

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# Physical, Iconographic and Symbolic Features of the Plectrum Some Reflections on Sound Production in Ancient Greek String Instruments

Felipe Aguirre

***Abstract—*** In this paper some of the relevant features of the πλῆκτρον within GrecoLatin tradition will be analyzed. Starting from the formal aspects (shape, materials, technical properties) and the archaeological evidence, some of its symbolic implications that emerge in the light of literary and iconographic analysis will be discussed. I shall expose that, in addition to fulfilling a purely physical function within the process of sound production, the πλῆκτρον was the object of a rich imaginery that provided it with an allegorical, metaphorical-poetic and even metaphysical dimension.

***Keywords—*** musicology, ethnomusicology, ancient greek music, plectrum, stringed instruments.

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# Peculiar Implications of Self Perceived Identity as Policy Tool for Transgender Recognition in Pakistan

Hamza Iftikhar

***Abstract***— The research study focuses on the transgender community's gender recognition challenges. It is one of the issues for the transgender community, interacting directly with the difficulties of gender identity and the lives of these people who are facing gender disapproval from society. This study investigates the major flaws of the transgender act. The study's goal is to look into the strange implications of self-perceived identity as a policy tool for transgender recognition. This policy tool jeopardises the rights of Pakistan's indigenous gender-variant people as well as the country's legal and social framework. Qualitative research using semi structured interviews will be carried out. This study proposes developing a scheme for mainstreaming gender-variant people on the basis of the Pakistani Constitution, Supreme Court guidelines, and internationally recognised principles of law. This would necessitate a thorough review of current law using a new approach and reference point.

***Keywords***— transgender act, self perceived identity, gender variant, policy tool.

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# Internal Security and Decolonization in US Press

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***Abstract—*** No research on the colonial system issues during the Cold War would be complete without studying the press of the participating parties. In order to give a detailed analysis of the international relationships in terms of the global transformations from the American point of view, the author draws relevant newspaper articles published after World War II. The results have shown changes to priority schemes as viewed in American social discourse during 1945. Roosevelt's plan for the dismantling of the colonial empires was gradually replaced with less radical plans, which presupposed using the colonial experience for the foreign policy of the USA. The materials of the American press of 1945 dedicated to the search for the most efficient optimal strategy of building relations with both colonial empires and with dependent territories show, among other things, a steady interest of American mass media интерес towards the negative and positive experiences of colonial policy. Thus, there emerged several new approaches towards assessment of the prospects of the colonial system in the American public discourse of late 1945. First approach: retention of all colonial empires, especially in the key points of the after-war world (Middle East, Indochina, Northern Africa). Second approach: retention of the British colonial empire capable of controlling (with the aid from the USA) the Mediterranean, the Middle East, and South-Eastern Asia; in that way, it will address two tasks, namely provision of valuable raw materials for the American economy, and controlling the rebel and national liberation forces. Third approach: replacement of colonial empires with American military presence in order to address the same tasks.

***Keywords—*** decolonization, public opinion, China, Asia, USA, World War II, press.

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# Built Environment and Crime in a South Korea Context

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## ABSTRACT

*The primary purpose of this paper is to test the applicability of environmental criminology in the case of South Korea. Also, it explores more effective strategies from a spatial planning perspective by taking control of diverse spatial planning factors. The study area is South Korea, and the base year was 2016. The relationship between the built environment and three crimes (theft, violence, sexual assault) was analyzed using the spatial econometric model. As a result, the best spatial regression models for violent crime rate and sexual assault rate are SEM and SAC, respectively. The most prominent finding is that the regression results in the three crimes are slightly different. The broken windows effect was negligible for significant crimes in South Korea. The influence of regional disorders on the incidence of crimes was marginal. In the three crime types, mixed land use affected raising crime rates, which is a line with some previous studies that mixed land use increases the likelihood of crime incidences. Unlike a series of relevant works, brighter nighttime light has not effectively decreased crimes in South Korea. In South Korea, CCTV did not play a role in deterring crimes. Lastly, socio-economic characteristics were closely connected with crime rates in South Korea. Findings of theft rate, violent crime rate, and sexual assault rate confirm the reliability of environmental criminology. Although this study has examined the likelihood of applying environmental criminology, further researches and discussions are followed for concrete plans.*

## KEYWORDS

*Crime, Environmental Criminology, Spatial Regression Models, Spatial Planning, South Korea*

## 1. INTRODUCTION

Why does crime highly concentrate in small areas? Academic efforts to this question date back to the 19th century when interests in the spatial distribution of crime were triggered in France. The spatial distribution of criminals and crime studied by the French government in 1825 is considered the first study on crime distribution (Bruinsma et al., 2018). Due to the lack of proper statistical models, the study could not provide substantial results, but the variability of crime across regions was identified. Only after the 20th century, researches on the spatial distribution of crime started to evolve in earnest. Through pioneering studies, such as the concentric zone model (Park & Burgess, 1925) and social disorganization theory (Shaw & McKay, 1942), the spatial characteristics that crime manifests in specific places were identified. In the late 1980s, with advances in computer technology, it was enabled to detect the concentration of crime in micro places (i.e., crime hot spots) with accuracy (Pierce, Spaar, & Briggs, 1988). The resulting spatial patterns of crime stirred interests among researchers in the tie between crime and place and eventually leading them to give birth to the environmental criminology.

Environmental criminology is a broad concept that crime is closely associated with the environmental conditions of places (Brantingham & Brantingham, 1981). This theory focuses on

offenders' decision-making process, noting that spatial circumstances can provide offenders with cues or opportunities (Weisburd et al., 1992). This perspective enables proactive criminal prevention through effective control of space because poor performance (inadequate knowledge on attractors, generators, and patterns of crime) of spatial conditions might lead to increasing the possibility of crime occurrence (Kamalipour, Memarian & Faizi, 2014). More importantly, proper design and effective use of the built environment can result in a reduction of fear of crime along with incidence, which will eventually lead to improved quality of life (Crowe, 2000). Various preceding researches have proved the potential and effectiveness of environmental criminology, and the achievement and development of the theory are ongoing (Bruinsma & Weisburd, 2014; Weisburd, Bruinsma, & Bernasco, 2009; Brantingham & Brantingham, 1981). Bruinsma et al. (2018) divides evolution stages of environmental criminology into four periods: (1) its beginning in Europe in the 19th century; (2) the heyday of the Chicago school of neighborhood research in the first half of the 20th century; (3) spatial research in Canada, Europe, and the United States from the 1980s; and (4) a more international focus on the study of crime in smaller spaces in the 21st century. These developmental stages directly inspired this research. The usefulness of environmental criminology should be documented in a broader range of countries to take a step forward, focusing on areas where relevant studies and applications are scarce.

The main contributions of this paper are threefold. First, this study tests the applicability of environmental criminology in the case of South Korea. Second, it explores more effective strategies from a spatial planning perspective by taking control of diverse spatial planning factors. Third, the study identifies common spatial planning practices that can apply to multiple crime types rather than a specific crime. Further explanation is needed as to why South Korea was chosen as a study area and why it is necessary to consider multiple crime types. In 2005, the Korean National Police Agency (KNPA) announced its plan to enforce environmental criminology, focusing on crime prevention through environmental design (CPTED), which has been vigorously fostered in the field of public policy (Shim, 2017). The scope of CPTED is expanding, particularly in the fields of redevelopment, criminal vulnerability, and school zones. In 2014, CPTED-oriented revision were enforced in the national building code and the redevelopment plan. In sum, South Korea has endeavored to embrace environmental criminology.

In analyzing the applicability of environmental criminology, it is required to consider various crime types to achieve generalization (Weisburd et al., 1992). On the policy front, generalized connections between crime and place suggest that generic environmental interventions may be both widely applicable and scalable (Jeffery, 1977). W first consider the five major crimes: homicide, robbery, theft, violent crime, and sexual assault. Due to their massive negative impact on society, these crimes are of the highest interest in almost all countries. Given the unique feature of crime occurrences in South Korea and insights from preceding studies, we finally selected three significant crimes: theft, violent crime, and sexual assault.

## 2. THEORETICAL BACKGROUND

Environmental criminology, which is recognized as a key strategy for preventing crime, has evolved systematically until recently. Various theories have been established and introduced so far, and the relevant studies have examined the core theories including, but not restricted to, the concentric zone model, social disorganization theory, routine activity theory, crime pattern theory, broken windows theory, environmental criminology, and CPTED. By looking into the development of environmental criminology, we can find reference points on Environmental criminology, while establishing a theoretical framework. In particular, the spatial and environmental factors covered in the related works are directly referenced for the selection of variables of regression analysis.

A pioneering work that figured out the relationship between crime and space is the concentric zone model (Park & Burgess, 1925). Although the main purpose of this creative study was to build a new conceptual framework to explain the complex urban land use with the concentric ring theory, this study illustrated where crime is high and which regional feature can lead to a high crime rate. Of the five classified land use zones suggested by the study, the second zone (the transition zone) showed a loss in a sense of community, resulting in large social disorganization, which in turn acted as a mechanism to increase deviant behavior and criminality. The argument that poor neighborhood conditions could impact much more on crime than other factors such as race and ethnicity has been supported by a bevy of studies until recently (Holzman-Escareno, 2015).

Social disorganization theory (Shaw & McKay, 1942), which is mentioned as one of the important theories in criminology, is basically spatial criminology because it succeeds Park & Burgess (1925). They analyzed the causes of higher rates of juvenile delinquency in the transition zone by Park & Burgess (1925) from social disorganization perspectives. The authors thought that social organization or cohesion at the neighborhood level is vital for combating crime, and therefore neighborhood in the lack of voluntary control through social cohesion and integration is more likely to be crime victims. In social disorganization theory, various characteristics of neighborhoods, such as demographic, economic, and spatial contexts, are considered essential factors for understanding crime. The macro approach to social disorganization theory is sometimes criticized (Eck & Weisburd, 2015), but its usefulness and generalizability is proved by many studies (Barnet & Mencken, 2002).

Routine activity theory (Cohen & Felson, 1979), one of the main sources of environmental criminology, pays heavily attention to the circumstances that can stimulate crime at any given space and time. It is presumed that crime occurs when the presence of a motivated offender, an accessible target exist, and the absence of capable guardians that could intervene is all met (Paulsen & Robinson, 2004). They argue that it is possible to curb the chance of crime in advance through appropriate guardians' activities. In addition, under the understanding of the crime situation that all three conditions are known, the opportunities, trends, and periods of crime occurrence are predictable in advance, which could allow people to carry out crime prevention. However, the lack of explanation of the connection between criminals and victims, and the lack of the individual's moral beliefs or the strength of social bonds, factors that can suppress crime, are perceived as limitations of routine activity theory (Haider & Lamtrakul, 2018).

Felson & Clarke's (1998) crime pattern theory focuses on the mechanism of crime, that is, crime occurs when a victim and a target intersect in a particular space. The theory describes crime move in space and time by taking three spatial features into accounts:  nodes (place), paths (actual paths), and edges (boundaries of districts). It is noteworthy that this theory explained the relation between space and crime based on the patterns of activity in human life. Also, the theory can be effectively used to clearly explain the spatial concentration of certain crime patterns. While crime pattern theory has a limitation in that it focuses only on crime at the individual level (Eck & Weisburd, 2015), the various theoretical advantages mentioned above show why the theory still holds an important position in environmental criminology.

Broken windows theory (Wilson & Kelling, 1982), the most familiar theory among various criminal theories, also has an important position in environmental crime. As Wilson & Kelling (1982) illustrated, disorder and crime are usually inextricably linked, in a kind of developmental sequence. In theory, the broken window is a symbolic expression of disordered space where it is likely to attract crime over time. This concept also includes the effect of spatial spillover effect in terms of crime, in which disorder space causes crime, which gradually extends to neighboring areas. Therefore, efforts to suppress the dangers of disordered space in advance are important for

the prevention of crime. Besides, the theory shows why policing should be concentrated in neighborhoods, in which are vulnerable to criminal invasion.

Even if several theories had had a profound effect on environmental criminology, before appearing Brantingham & Brantingham (1981, 1984), environmental criminology existed as fragmented theories. Many agree that they have provided valuable implications for improving concepts and applications of environmental criminology for a long time since the 1980s. According to Brantingham & Brantingham (1991), a crime occurs only when space, time, law, offender, and target or victim come together. Conversely, if one of the factors that constitute a crime is missing, no crime occurs. In describing the five factors as reasons for crime, this theory deals with strategies for the physical environment and nature of neighborhood structures. In particular, by systematically explaining the connection between land use, traffic patterns, urban design and daily activities, and movements of victims and offenders, environmental criminology contributed to crime prevention. From a spatial planning point of view, these articles can be highly valued in that it provides a theoretical framework for understanding spatial planning's roles to curb crime through land use, transportation, and facility planning, which are the central part of spatial planning. Like other relevant theories, this study also has limitations. Too much emphasis on place-based factors and the lack of consideration of the spatial patterns of crime have been pointed out as representative limitations of the theory (Cozens, Saville & Hillier, 2005).

The last theory needed to review is CPTED. The pioneering concept of this theory is Newman's (1973) defensible space. Newman 's ideas centered on public housing design helped to shape environmental criminology as a new area of focus in urban housing and accessibility (Gibson, 2016). While Newman's theory focuses on crime prevention activities primarily from an architectural point of view, CPTED aims a comprehensive approach. In other words, it would design a safe building and place from crime by using a wide range of environmental design elements that can minimize the chance of crime. There is a criticism that CPTED is a defense-oriented strategy and ignores crime motives or offenders (Cozens, Saville & Hillier, 2005). However, CPTED has been receiving the most attention in environmental criminology since 2000, and its application has been expanded to developed countries such as the United Kingdom, Australia, the United States, and Singapore due to its successful crime-reduction capability. In South Korea, the study area of the current paper, CPTED has been actively implemented in recent years, and its utilization is expected to continue to increase at a fast speed.

The two key takeaways can be drawn from the theory review on environmental crime. First, the research areas in space and crime have been greatly expanded and achieved remarkable theoretical development. Given the enormous impact of place on crime, the rapid growth of environmental criminology is foreseeable. Second, previous researches illustrate the usefulness and crucial position of environmental crime. In modern criminology in which proactive crime prevention activities are recognized much more importantly, the great influence of environmental criminology is more likely to be strengthened in the future. The present study aims to complement the existing researches in two aspects. For systematically understanding determinants of crime from the lens of environmental crime, it is necessary to more comprehensively identify the effects of spatial planning factors on crime. The study investigates the possibility of spatial factors for proactive crime prevention strategies. As noted, until now, environmental crime has been active in some developed Western countries. To expand the validity and practicality of environmental crime across the globe, new researches should be conducted in countries where relevant research is scarce. The study ascertains the applicability of environmental criminology in South Korea, where the interest of environmental criminology has been low. This effort can contribute to the generalizability of environmental criminology.

## 3. Study Area

The study area is South Korea, and the base year is in 2016. The study area covers almost all South Korea, except for some islands where there are no reliable materials or where spatial adjacency for spatial regression models is obscure to determine. Using the basic statistics provided by The Korean National Police Agency (2018), the crime trends in Korea are as follows. As of 2016, 1,849,450 total crimes (3,577 crimes per 100,000 population) occurred in South Korea (Korean National Police Agency, 2018). Over the last ten years (2009-2018), about 1.8 million crimes per year have occurred in South Korea and have maintained the crime trends. From 2014 to 2018, sexual assault rates increased by 12%, while theft and violent crime rates decreased by 34% and 1%, respectively. Given the fact that homicide and robbery rates were also reduced by 13% and 39, respectively, in the same period, sexual assault was the only increase in the five major crimes. Thus, social concerns about sexual assault in South Korea have arisen.

Figure 1 displays the outlines of the study area and geographical distributions of theft, violent, and sexual assault rates (per 10,000 population) in 2016. The study area consists of 216 police districts. Due to the principle of boundary demarcation that actively considers people size, the police districts in and near big cities such as Seoul, the capital of South Korea, is very smaller than other regions. Figure 1 offers some baseline for our understanding of the distribution of the three crime rates and their variation across districts. As of 2016, there are 36.5 theft, 55.6 violent crime, and 5.0 sexual assault occurrences per 10,000 population in the study area (Korean National Police Agency, 2018). The spatial distribution pattern reveals the differences between the three types of crime rates. The theft crime rates tend to be relatively high in and surrounding big cities. The two types of crime rates are generally higher in the northern regions than in the southern regions when the study area is divided into two parts (south and north). Examining the link between the three types of crimes with different spatial distributions and environmental criminology can provide critical implications on how to contrive and develop effective crime prevention policies.



| (a) Outline of Study Area | (b) Theft Crime Rates |
|---|---|
| (C) Violent Crime Rates | (d) Sexual Assault Crime Rates |
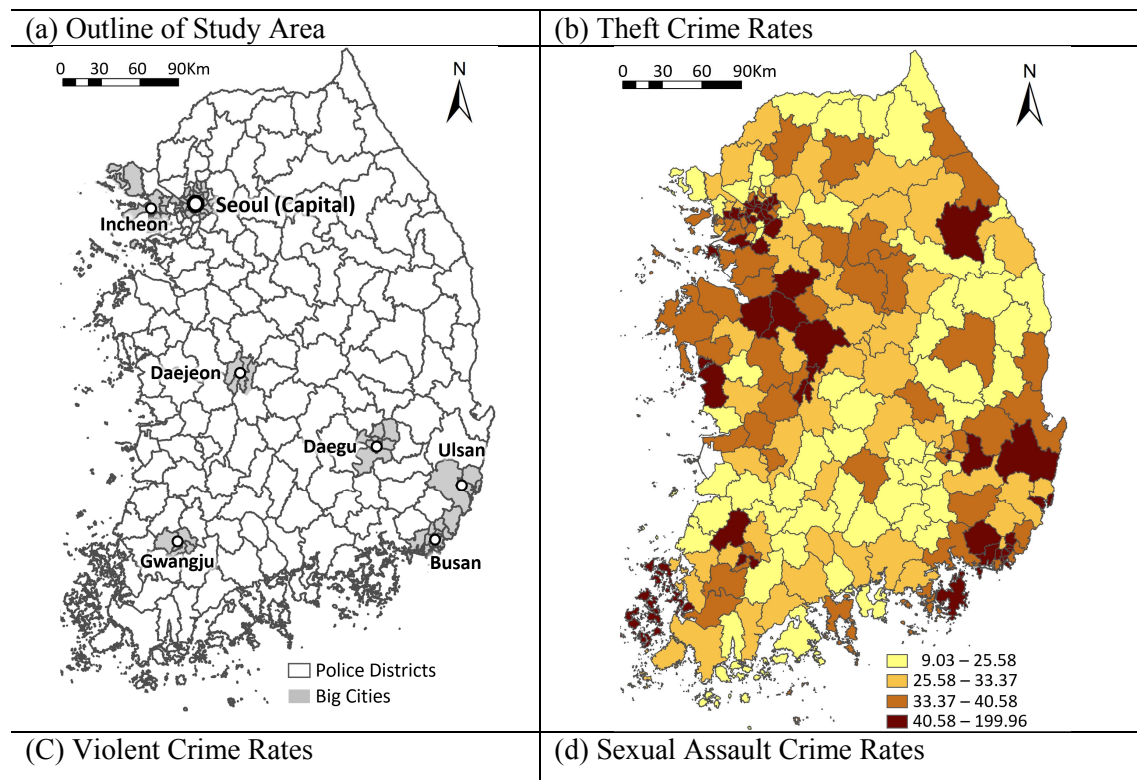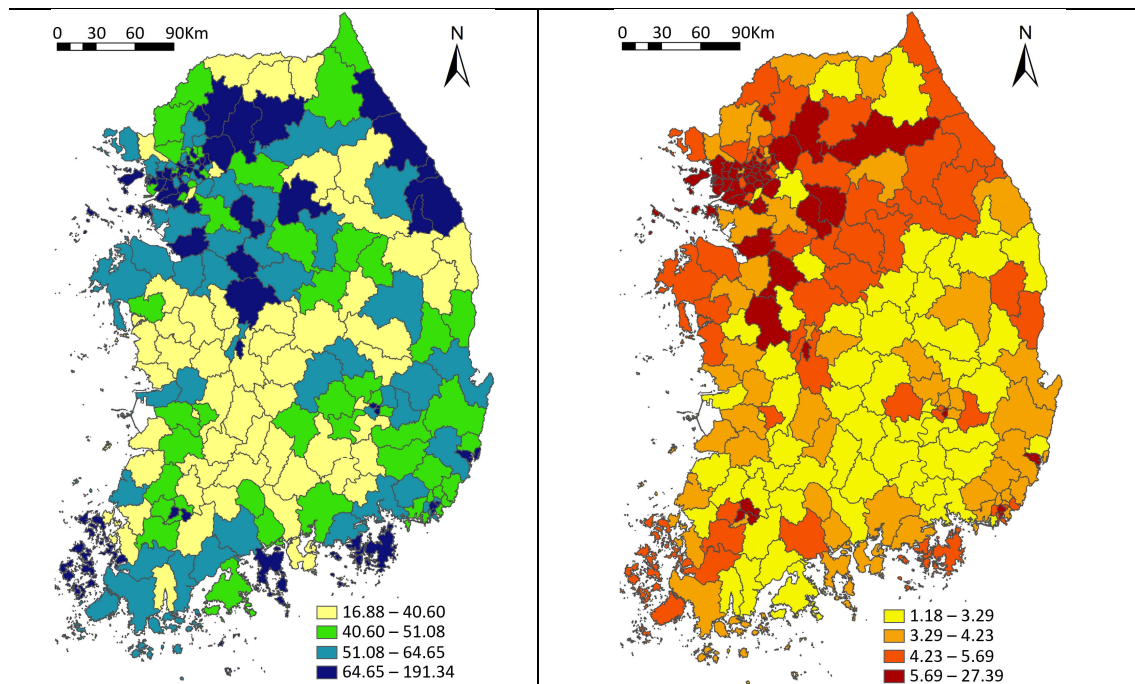
Note: Respective crime rates refers to the number of crimes per 10,000 population.

Figure 1. Study Areas and Spatial Distribution of Crime Rates in 2016

## 4. Methodology and Variable Selection

### 4.1. Spatial Regression Models

The classical linear multiple regression models presume that observations or regions are independent of one another. This assumption, however, is often unrealistic. Spatial data such as crime data tends to be dependent between adjacent regions, a phenomenon known as spatial autocorrelation (also referred to as spatial dependence). The presence of spatial autocorrelation will produce estimates that are biased and inconsistent in regression (Lesage & Fischer, 2008). Various spatial linear regression models have been developed to address the issue of spatial autocorrelation (Keitt et al. 2002) and are widely used in crime studies. The validity of applying spatial regression is highly associated with the existence of spatial autocorrelation. If spatial data has spatial autocorrelation, it is preferable to employ spatial regression. The Global Moran's I statistic that was introduced by Moran (1948) and elaborately formulated by Cliff & Ord (1981) is most often used for measuring spatial autocorrelation. The Global Moran's I value ranges from 1 (clustered) to -1 (dispersed). The value of 0 refers to no spatial autocorrelation indicating random distribution. The Global Moran's I offers z-score and p-value representing whether the outputs are statistically significant.

Table 1. Results of Spatial Autocorrelation Tests for Crime Rates

| Crime Type | Global Moran's I | z-score | p-value |
|---|---|---|---|
| Theft rate (log) | 0.2595 | 7.2851 | 0.0000 |
| Violent crime rate (log) | 0.2521 | 6.8141 | 0.0000 |
| Sexual assault rate (log) | 0.4111 | 11.2089 | 0.0000 |

Table 1 shows the results of spatial autocorrelation tests for the three crime rates. We applied the logarithmic transformation to the three crime rates (see the next section 4-2 for the details) and a queen spatial matrix. The three crime rates had all a positive spatial autocorrelation (clustered) with high statistical significance (p<0.001). Hence, spatial linear regression models should be exploited to yield efficient and unbiased estimates by reflecting spatial autocorrelation.

Spatial linear regression models have been developed in a wide range of forms. Given the cross-sectional crime data, the current paper employs four basic spatial linear regression models (Lesage & Pace, 2009): a spatial lag model (SLM), a spatial Durbin model (SDM), a spatial error model (SEM), and a spatial autoregressive model (SAC). SLM is an extension of the traditional regression model, ordinary least squares (OLS), and its specific form is as follows:

$$y = \rho \text{W} y + \alpha \tau_n + X\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \text{ Eq. (1)}$$

where $y$ and X refer to the dependent and independent variable in the form of a column vector; W indicates the weight matrix (here queen matrix), and $\tau_n$ is a one-column vector; ε is the error term and $\sigma^2$ is the variance of the error term; $I_n$ means the $n$ x $n$ unit matrix. $\alpha$, β, and ρ are coefficients to be estimated; Spatial lag effect can be captured by ρ, and thus its value and statistical significance are the most important to identify the impact of spatial autocorrelation.

SDM, also known as a special case of SLM, is developed to reflect spatial dependence both dependent and independent variables at the same time. SDM adds spatial lag effect to the independent variable as follows:

$$y = \rho \text{W} y + \alpha \tau_n + X\beta + \text{W}X\gamma + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \text{ Eq. (2)}$$

where γ is the coefficient of spatial lag on independent variables.

SEM is presented in Eq. (3), where its error terms have spatial dependence:

$$y = X\beta + \mu, \mu = \theta \text{W} \mu + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \text{ Eq. (3)}$$

SAC assumes that spatial dependency exhibits in both the dependent variables $y$ and the error term ε where spatial weight $W_1$ and $W_2$ may or may not be equal.

$$y = \alpha \tau_n + \rho W_1 y + X\beta + \mu, \mu = \theta W_2 \mu + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \text{ Eq. (4)}$$

Among various tools for spatial linear regression models, We used in R with the "spdep" package (R Development Core Team, 2012).

## 4.2. Variables and Data

We summarize the variables and the data source used in the regression analysis in Table 3. The dependent variables are theft, violent crime, and sexual assault rates. The distribution of all three dependent variables is skewed to the left, which does not meet the assumptions of parametric statistical tests. We utilize the logarithmic transformation to approximately conform to a more normal distribution (Kurlychek & Johnson 2004). The independent variables consist of the spatial environmental variables mainly used in the environmental criminology discussed above, and the police force variable and socio-economic variables that are known to be associated with crime at the neighborhood or region level. Each independent variable by three categories is as follows.

- Spatial environmental variables: vacant house, housing deterioration, intersection density, mixed land use, nighttime light

- Police force variables: police officer, closed-circuit television (CCTV)

- Socio-economic variables: youth population, single-person household, concentrated disadvantage index (CDI), company

As in other countries, most of the statistics in South Korea are based on administrative boundaries. However, the administrative boundaries and police districts in South Korea do not match, and thus constructing data for crime research involves many challenging issues. To address this, We extracted the boundaries of the police districts in ArcGIS 10.6.0, and then manually matched administrative datasets with the police districts. Except for independent variables that can be easily understood through Table 3, we further explain the process of constructing variables in detail.

The intersection density was established through precise spatial analysis techniques. We first searched for road intersections with the spatial join tool and then found intersections where three or more overlap, which is defined as the road intersection for this analysis. The road intersections extracted from the study area were 1,696,095, and the number of intersections per 10,000 population was used as the final variable. To capture mixed land use, we accepted the entropy index, the most commonly used index for representing the mixed land use (Bordoloia et al., 2013). Entropy index is formulated as:

$$Entropy = \sum_j P_J \times \frac{In(P_j)}{\ln(J)}$$

where, $P_j$ denotes the proportion of the total land area of $j$ land use category in a police district, and $J$ indicates total land uses in a police district. The higher value of entropy represents more mixed land use. For measuring mixed land use, we adopted the five specific land uses: residential, commercial, industrial, public, and amusement land use.

The U.S. National Oceanic and Atmospheric Administration (NOAA) provides nighttime lights calculated from weather satellite recordings as an annual time series. Of the three sources, we used "vcm-orm-ntl" (VIIRS Cloud Mask-Outlier Removed-Nighttime Lights). The sum of nighttime light intensity is extracted in police districts. CDI is an indicator of concentrated disadvantage at a local level. We adopted the two most dominant variables to reveal the local socio-economic level in South Korea: municipal financial independence rate and university graduate percent. CDI was gained by normalizing these two variables and taking their averages using Z-score. Many environmental and socio-economic variables affecting crime often involve a multicollinearity problem in regression. To mitigate a multicollinearity issue, the logarithmic transformation technique is applied for the three independent variables: nighttime light, youth population, and company.

The independent variables in this study have been widely utilized in relevant studies. Thus, the claims and findings of related works can offer a baseline for comparing existing studies and results of South Korea. A tie between neighborhood environment and crime has long been explored and theorized in criminal-related researches. According to Broken Windows theory (Wilson & Kelling, 1982), the variance in crime is explained by the physical deterioration of a neighborhood. Many studies have found that this argument is highly persuasive. (Katz et al., 2011; Goodstein & Lee, 2010; Spelman, 1993; Skogan, 1990). We take the vacant house and housing deterioration into account to see whether this claim can be supported in South Korea.

Table 2. Variable Definitions and Sources

| Variable | Description | Source |
|---|---|---|
| <u>Dependent</u> | | |
| Theft rate (log) | Occurrence per 10,000 population | Korean National Police Agency |
| Violent crime rate (log) | Occurrence per 10,000 population | Korean National Police Agency |
| Sexual assault rate (log) | Occurrence per 10,000 population | Korean National Police Agency |
| | | |
| <u>Independent</u> | | |
| Vacant house | Proportion of vacant house to total house | Statistics Korea |
| Housing deterioration | House building year | Statistics Korea |
| Intersection density | Number of intersections per 10,000 population | Ministry of Land, Infrastructure and Transport of South Korea |
| Mixed land use | Entropy index (residential, commercial, industrial, public, and amusement land use) | Ministry of Land, Infrastructure and Transport of South Korea |
| Nighttime light (log) | Sum of nighttime light intensity | U.S. National Oceanic and Atmospheric Administration (NOAA) |
| Police officer | Population per a police officer | Korean National Police Agency |
| CCTV | Number of CCTVs per 10,000 population | Korean National Police Agency |
| Youth population (log) | Proportion of 15-29 year-old to total population | Statistics Korea |
| Single-person household | Proportion of one-person Household to total household | Statistics Korea |
| CDI | Combination both municipal financial independence rate and university graduate percent | Statistics Korea |
| Company (log) | Number of companies per 10,000 population | Statistics Korea |

*Note: CCTV and CDI indicate Closed-circuit television and Concentrated Disadvantage Index, respectively.*

Intersection density stands for the connectivity of street networks, and higher intersection density indicates higher street connectivity (Sallis et al., 2009). Higher street connectivity may provide criminals with diverse routes of escape and weaken access controls, leading to increasing crimes (Sohn, 2016; Loukaitou-Sideris, 1999; Brantingham & Brantingham, 1993). On the contrary to this, the construction of a pedestrian-friendly environment through higher street connectivity would be effective in preventing crime by increasing natural surveillance (Cozens, 2008; Hillier & Sahbaz, 2008).

For a similar reason to the intersection density, conflicting claims and evidence of mixed land use on crime exist simultaneously. On the one hand, mixed land use creates a situation that residents and nonresidents converge in time and space (Brantingham & Brantingham, 1995), exposing residents to more crime. Similarly, some studies posit that mixed land use, which degrades residents' social control, acts as a mechanism for increasing crime (Reynald, 2010; Sampson & Raudenbush, 1999). On the other hand, mixed land use exerts a salutary effect on crime (Browning et al., 2010; Talen, 1999; Jacobs, 1961). The underlying of this argument is that mixed land use enhances mutual cohesion and facilitate social control, decreasing crime rates. One interesting point is that this assertion is supported by many spatial planners who believe that

mixed land use is a complement to the strict zoning system (e.g., a primary strategy of New Urbanism). Along with two conflicting arguments, there is also the assertion that the relationship between land use diversity and crime may vary by offense type (Wo, 2019; Hayslett-McCall, 2002).

A sufficient amount of lighting for activities during the night is one of the primary strategies of CPTED because it helps maintain visual acuity and surveillance in nighttime environments (Chalfin et al., 2019). Articles have contended that higher nighttime night intensity allows people to enhance surveillance opportunities, resulting in inviting fewer criminals (Cozens & Love, 2015; Weisel, 2002). Contrastively, lower nighttime night intensity may be combined with exposure to offenders, resulting in a higher probability of crime occurrences.

The relationship between the police force and crime rates is one of the popular topics in criminology for a long time. The effect of police resources on decreasing crime rates has been controversial. Evans & Owens (2007) and Levitt (2002) maintains that police resources can reduce crime by deterring potential offenders. However, findings that a significant inverse and no relationship between the number of police officers and crime rates are found (Kim & Lee, 2011; Kleck & Barnes, 2010; Marvell & Moody, 1996). Although the crime-reduction effect of CCTV depends on the characteristics of the locations Lim et al. (2016), a great deal of research has agreed with the proof that CCTV has a positive impact on the reduction of crime.

It is now a truism that socio-economic feature is one of the most influential factors associated with criminal behavior. Hirschi & Gottfredson (1983) opine that the age-crime relationship is invariant, and crime rises rapidly in early adolescence, peaks in late adolescence, rapidly decrease throughout the 20s. There are varied opinions on the realistic span of the age-crime curve, but many studies support the invariant age-crime parameters (Ulmer & Steffensmeier, 2014; Kanazawa & Still, 2000). Single-person households are more vulnerable to crime because of less guardianship (Nicolaas et al., 2010; Dignan, 2005). Since the Chicago School, social or neighborhood disadvantages play a role in explaining criminal behavior (Becker, 2018). As noted earlier, an enormous body of work on environmental criminology has paid much attention to neighborhood disadvantages as a key factor in increasing crimes. We take advantage of CDI to examine whether this claim is appropriate in a South Korea context.

The association between the number of companies and crime can be explained from two different perspectives. First, as discussed above, according to the social control perspective, a large number of companies generate more floating populations, which can exert a salutary effect (advantage surveillance) or deleterious effect (disadvantage social control) on crime. The other is the regional economic point of view. The higher the number of companies, the lower the probability of crime, since regions with a poor economic condition is more likely to have more crime rates (Hoghe et al., 2011; Andresen, 2006).

## 5. Results

### 5.1. Regression Model Selection
Prior to explaining the determinants of crime rates, we choose the most appropriate spatial regression model by crime type. Of all four spatial regression models, we select one model that has the best statistical power. The model selection is determined by two steps. As spatial regression models are applied, the first step should be statistically significant for $\rho$ and $\gamma$, meaning spatial autocorrelation (at least $p < 0.05$). In the second step, we select the appropriate model based on the Akaike information criterion (AIC) value. The model with the smallest AIC is preferred. To take the theft rate as an example, except for SAC, all meet the first step because $\rho$ and $\gamma$ are statistically significant. Since the AIC value of SEM is the smallest among the three models, the

best model for the theft rate is SEM. Using this same approach, the best spatial regression models for violent crime rate and sexual assault rate are SEM and SAC, respectively. In the following section, we will explain the regression results for the three types of crimes based on the selected model.

Table 3. Comparison of Spatial Regression Models and Model Selection

| Crime Type | Statistics | SLM | SDM | SEM | SAC |
|---|---|---|---|---|---|
| Theft rate | AIC | 130.18 | 134.64 | 122.94 | 122.87 |
| | ρ | 0.1878(**) | 0.3123(***) | - | -0.2119 |
| | γ | - | - | 0.3380(***) | 0.5004 |
| | Model Selection | - | - | O | - |
| Violent crime rate | AIC | 22.06 | 14.98 | 8.37 | 11.27 |
| | ρ | 0.1716(*) | 0.3601(***) | - | -0.2053 |
| | γ | - | - | 0.4253(***) | 0.5542(***) |
| | Model Selection | - | - | O | - |
| Sexual assault rate | AIC | 38.44 | 28.09 | 34.56 | 33.67 |
| | ρ | 0.0854 | 0.1047 | - | -0.2363(*) |
| | γ | - | - | 0.2701(*) | 0.5140(***) |
| | Model Selection | - | - | - | O |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$*

## 5.2. Regression Results

Table 4 displays the descriptive statistics for each variable adopted in the analyses. Variance inflation factor (VIF) values for all models are below 6.6, indicating no problems of multicollinearity.

Table 4. Descriptive Statistics of Variables (N=216)

| Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Theft rate | 12.70 | 0.43 | 11.41 | 14.51 |
| Violent crime rate | 13.16 | 0.37 | 12.04 | 14.46 |
| Sexual assault rate | 10.69 | 0.49 | 9.38 | 12.52 |
| Vacant house | 8.66 | 4.87 | 0.51 | 20.79 |
| House deterioration | 30.43 | 9.60 | 11.72 | 49.61 |
| Intersection density | 49.47 | 82.79 | 0.81 | 493.19 |
| Mixed land use | 0.48 | 0.40 | 0.05 | 1.39 |
| Nighttime light | 8.66 | 0.77 | 6.58 | 10.62 |
| Police officer | 489.25 | 183.13 | 125.37 | 1,021.10 |
| CCTV | 48.25 | 28.78 | 10.41 | 206.70 |
| Youth population | 2.84 | 0.18 | 2.38 | 3.19 |
| Single-person household | 30.31 | 5.32 | 17.70 | 45.10 |
| CDI | 0.00 | 0.85 | -1.11 | 3.77 |
| Company | 6.69 | 0.29 | 6.14 | 8.57 |

Table 5 exhibits the regression's result of the theft crime rate derived from SEM. The vacant house had a negative impact on the theft crime rate, and house deterioration had no relationship with the theft crime rate. In light of these results, neighborhood deterioration was not a direct connection to theft crime in South Korea. Unlike the intersection density, more mixed land use increased the theft crime rate (p <0.01). This finding is in line with previous arguments that more mixed land use can cause reducing social control and exposing residents to more crime. The higher the nighttime light intensity, the higher the likelihood of theft crime (p <0.001). In general,

bright nighttime light can be an effective strategy in preventing crime by increasing surveillance, but this notion was not valid for the theft crime in South Korea. Instead, bright nighttime light can increase the amount of nighttime activity, augmenting the chance of being exposed to crime. Based on the lower theft crime rate, the larger the population in charge of police officers, the distribution of police force in South Korea is relatively efficient for repressing theft crime. Unlike police deployments, CCTV was not associated with curbing theft crime rate. With the exception of the youth population, socio-economic variables were closely related to the theft crime rate. The theft crime rate increased with more single-person households (p <0.001), higher CDI (p <0.001), and a larger number of companies (p <0.05). Less guardianship, neighborhood disadvantages, and more floating populations can be said to be directly associated with the theft crime rate.

Table 5. Regression Result of Theft Crime Rate (SEM)

| Variable | Estimate | Std. Error | Z value | |
|---|---|---|---|---|
| Intercept | 8.6148 | 1.0121 | 8.5116 | (***) |
| Vacant house | -0.0205 | 0.0083 | -2.4560 | (*) |
| House deterioration | -0.0689 | 0.0466 | -1.4795 | |
| Intersection density | 0.0648 | 0.0524 | 1.2375 | |
| Mixed land use | 0.1736 | 0.0645 | 2.6924 | (**) |
| Nighttime light | 0.1954 | 0.0533 | 3.6657 | (***) |
| Police officer | -0.0011 | 0.0027 | -4.0671 | (***) |
| CCTV | 0.0045 | 0.0090 | 0.5034 | |
| Youth population | -0.1806 | 0.2407 | -0.7504 | |
| Single-person household | 0.0182 | 0.0067 | 2.7399 | (***) |
| CDI | 0.1286 | 0.0499 | 2.5782 | (***) |
| Company | 0.2098 | 0.1014 | 2.0694 | (*) |
| γ | 0.3380(***) | - | - | |

*AIC: 122.94; Log likelihood; -47.46; \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001*

Table 6 represents the determinants of violent crime rate based on SEM. Even if house deterioration had a negative effect on the violent crime rate, a more reasonable interpretation is that neighborhood deterioration was not a close correspondence with the violent crime rate in South Korea. The impact of intersection density, mixed land use, and nighttime light on the violent crime rate was consistent with the results of the theft crime above. That is, the effect of intersection density was not confirmed, and more mixed land use (p <0.001) and brighter nighttime light (p <0.001) increased violent crime occurrence. The distribution of police officers was effective in combating violent crimes (p <0.05), but there was no link between CCTV and violent crimes. Districts with more youth population were more vulnerable to violent crime (p <0.01), indicating that there was a strong age effect on the violent crime in South Korea. In areas with high CDI, the violent crime rates were lower (p <0.001). Conversely, it can be said that violent crimes tend to occur around richer places in South Korea. A number of companies also acted as inviting more violent crimes (p <0.001).

Table 7 shows the regression result of sexual assault crime rate from SAC. The sexual assault crime rate was not a close correspondence with the physical conditions of the neighborhood. Of the three crime types, intersection density was the only correlated with sexual assault crime rate. The more the intersection density, the higher the odds of sexual assault crime (p <0.05), demonstrating that higher street connectivity is favorable for the criminal behavior of sexual assault in South Korea. Mixed land use and nighttime light play a critical role in raising the probability of sexual assault crime (p <0.001). The police force both geographical distribution of police officers and CCTV was not a connection to sexual assault crime rate. Among socio-economic variables, single-person households and a number of companies were associated with sexual assault crime. In districts where many single-person households live, sexual assault crime rate is more likely to be higher (p <0.001). Given that women are the most victims of sexual

assault crime in South Korea, areas with more women living alone were more susceptible to be disclosed to sexual assault crime. As with the other two types of crime, areas with a larger number of companies were more likely to be exposed to sexual assault crime (p <0.001).

Table 6. Regression Result of Violent Crime Rate (SEM)

| Variable | Estimate | Std. Error | Z value | |
|---|---|---|---|---|
| Intercept | 7.7885 | 0.7812 | 9.9701 | (***) |
| Vacant house | -0.0134 | 0.0640 | -0.2096 | |
| House deterioration | -0.0738 | 0.0364 | -2.0247 | (*) |
| Intersection density | 0.0605 | 0.0405 | 1.4937 | |
| Mixed land use | 0.1768 | 0.0505 | 3.4977 | (***) |
| Nighttime light | 0.1402 | 0.0409 | 3.4278 | (***) |
| Police officer | -0.0042 | 0.0021 | -2.0407 | (*) |
| CCTV | 0.0050 | 0.0069 | 0.7333 | |
| Youth population | 0.4389 | 0.1850 | 2.3731 | (**) |
| Single-person household | 0.0052 | 0.0051 | 1.0241 | |
| CDI | -0.1092 | 0.0397 | -2.7490 | (***) |
| Company | 0.4982 | 0.0772 | 6.4552 | (***) |
| γ | 0.4253(***) | - | - | |

*AIC: 8.37; Log likelihood; 9.81; *p < 0.05, **p < 0.01, ***p < 0.001*

Table 7. Regression Result of Sexual Assault Crime Rate (SAC)

| Variable | Estimate | Std. Error | Z value | |
|---|---|---|---|---|
| Intercept | 10.8992 | 1.9288 | 5.6508 | (***) |
| Vacant house | -0.0744 | 0.0674 | -1.1044 | |
| House deterioration | -0.0128 | 0.0389 | -0.3282 | |
| Intersection density | 0.0109 | 0.0043 | 2.5294 | (**) |
| Mixed land use | 0.1936 | 0.0560 | 3.4590 | (***) |
| Nighttime light | 0.1447 | 0.0429 | 3.3737 | (***) |
| Police officer | -0.0034 | 0.0022 | -1.5628 | |
| CCTV | -0.0070 | 0.0072 | -0.9730 | |
| Youth population | 0.1541 | 0.1950 | 0.7901 | |
| Single-person household | 0.0142 | 0.0053 | 2.6905 | (***) |
| CDI | 0.0581 | 0.0443 | 1.3121 | |
| Company | 0.4703 | 0.0858 | 5.4837 | (***) |
| ρ | -0.2363(*) | - | - | |
| γ | 0.5140(***) | - | - | |

*AIC: 33.67; Log likelihood; -1.83; *p < 0.05, **p < 0.01, ***p < 0.001*

We summarize the regression results as follows. The most prominent finding is that the regression results in the three crimes are slightly different. A generalized strategy applicable to all crimes is required (Weisburd et al., 1992) for more effective anti-criminal operations, but the current analyses show that this approach is challenging in reality. Nevertheless, the same influential variables in all three crime types can be adopted as a generalized strategy for preventing major crimes in South Korea.

The broken windows effect was negligible for significant crimes in South Korea. The result is consistent with Sampson & Raudenbush (1999) 's argument that increased disorder did not cause serious crime. Considering the environmental characteristics of physical activity in South Korea, such a result can be convincing. Since 1995, a year when the local autonomy system was regularized, local governments have made great efforts to improve their physical properties. As a

result, the influence of regional disorders on the incidence of crimes was marginal. Another interpretation is possible. In South Korea, neighborhood deterioration in rural areas is more severe than in urban areas, and due to the low crime rate in rural areas, the effects of the broken window did not work.

In the three crime types, mixed land use affected raising crime rates, which is a line with some previous studies that mixed land use increases the likelihood of crime incidences (Reynald, 2010; Brantingham & Brantingham, 1995). South Korea has run the zoning system to control land use, which is equivalent to the U.S, but the level of mixed land use is very high, compared to the countries of the world. Although new planning ideas such as New Urbanism encourage human activities through mixed land use, mixed land use in South Korea has been found to cause crimes. Thus, proper intervention is needed from a crime-prevention standpoint.

Unlike a series of relevant works, brighter nighttime light has not been effective in decreasing crimes in South Korea. The result can be understood through South Korea's unique nightlife. South Korea is one of the countries with the most developed nightlife. Even after midnight, it is common for many people to enjoy the nightlife in various regions. Most restaurants and convenience facilities are open until late dawn, welcoming people who want to entertain nightlife. In areas with brighter nighttime light, the nightlife is more intense, and thus those engaged in nightlife are more subject to crimes. In this regard, policies that effectively control and manage nightlife may be more practical than offering brighter nighttime light.

In South Korea, CCTV did not play a role in deterring crimes. As Lim et al. (2016) noted, the crime prevention effect of CCTV is directly related to its location, so efforts to increase the efficiency of CCTV location will emerge as one of the essential crime prevention strategies in South Korea. This study proved why location-oriented approaches in terms of CCTV should be accompanied by, not just the number of CCTVs in districts.

Lastly, socio-economic characteristics were closely connected with crime rates in South Korea. In all three crimes of the study, a number of companies allured offenders to commit crimes. In violent crime, the impact of youth populations was identified. A district with more single-person households tends to have higher theft and sexual assault crime rates. CDI increased theft crime and decreased sexual assault crime vice versa. The Chicago School's argument that the neighborhood disadvantages cause more offenses is still valid in South Korea. Thus, efforts to improve neighborhood environments will be regarded as an important policy for crime-free areas.

## 6. Conclusion

Can environmental criminology be an effective strategy to curb crimes in South Korea? Yes, it can. Findings of theft rate, violent crime rate, and sexual assault rate confirm the reliability of environmental criminology. Although this study has examined the likelihood of applying environmental criminology, further researches and discussions are followed for concrete plans. From effective spatial planning to policy applications, many research fields have not yet been validated from the lens of environmental criminology. With the interest of the public, follow-up studies should dive deeper into finding practical spatial planning and policy strategies to suppress crimes.

Since the spatial autocorrelation of crime rates is confirmed in South Korea, it will be necessary to consider spatial autocorrelation in subsequent studies actively. Under the premise of spatial autocorrelation in crime data, follow-up works should produce more general outputs by actively applying spatial panel regression models rather than cross-sectional analysis. Additionally, microscopic studies will be preferred for mitigating structural limitations of aggregated data (e.g.,

ecological fallacy and modifiable areal unit problem). Further, environmental criminology should be active use for crime prediction. As with this study, studies analyzing the effects, impacts, and possibilities of environmental criminology in various countries or regions should continue to extend its valid generalization and utilization.

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# Estimating View-Through Ad Attribution from User Surveys Using Convex Optimization

Yuhan Lin, Rohan Kekatpure, Cassidy Yeung

*Abstract—* In Digital Marketing, robust quantification of View-through attribution (VTA) is necessary for evaluating channel effectiveness. VTA occurs when a product purchase is aided by an Ad but without an explicit click (e.g. a TV ad). A lack of a tracking mechanism makes VTA estimation challenging. Most prevalent VTA estimation techniques rely on post-purchase in-product user surveys. User surveys enable the calculation of channel multipliers, which are the ratio of the view-attributed to the click-attributed purchases of each marketing channel. Channel multipliers thus provide a way to estimate the unknown VTA for a channel from its known click attribution. In this work, we use Convex Optimization to compute channel multipliers in a way that enables a mathematical encoding of the expected channel behavior. Large fluctuations in channel attributions often result from overfitting the calculations to user surveys. Casting channel attribution as a Convex Optimization problem allows an introduction of constraints that limit such fluctuations. The result of our study is a distribution of channel multipliers across the entire marketing funnel, with important implications for marketing spend optimization. Our technique can be broadly applied to estimate Ad effectiveness in a privacy-centric world that increasingly limits user tracking.

*Keywords—* digital marketing, survey analysis, operational research, convex optimization, channel attribution.

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# Building Brand Equity in a Stigmatised Market: A Cannabis Industry Case Study

Sibongile Masemola

***Abstract***— In 2018, South Africa decriminalised recreational cannabis use and private cultivation, since then, cannabis businesses have been established to meet the demand. However, marketing activities remain limited in this industry and businesses are unable to disseminate promotional messages, however as a solution, firms can promote their brands and positioning instead of the actual product (Bick, 2015). Branding is essential to create differences among cannabis firms and to attract and keep customers (Abrahamsson, 2014). Building cannabis firms into brands can better position them in the mind of the consumer so that they become and remain competitive.

The aim of this study was to explore how South African cannabis retailers can build brand equity in a stigmatised market, despite significant restrictions on marketing efforts. Keller's (2001) customer-based brand equity (CBBE) model was used as the as the theoretical framework and explored how cannabis firms build their businesses into brands through developing their brand identity, meaning, performance and relationships, and ultimately creating brand equity.

The study employed a qualitative research method, using semi-structured in-depth interviews among 17 participants to gain insights from cannabis owners and marketers in the recreational cannabis environment. Most findings were presented according to the blocks of CBBE model. Furthermore, a conceptual framework named the stigma-based brand equity (SBBE) model was adapted from Keller's CBBE model to include an additional building block that accounts for industry-specific characteristics unique to stigmatised markets. Findings revealed the pervasiveness of education and its significance to brand building in a stigmatised industry. Results also demonstrated the overall effect stigma has on businesses and their consumers due to the longstanding negative evaluations of cannabis. Hence, through stigma-bonding, brands can develop deep identity-related psychological bonds with their consumers that will potentially lead to strong brand resonance.

This study aims to contribute business-relevant knowledge for firms operating in core-stigmatised markets under controlled marketing regulations, by exploring how cannabis firms can build brand equity. Practically, this study presents recommendations for retailers in stigmatised markets on how to destigmatise, build brand identity, create brand meaning, elicit desired brand responses, and develop brand relationships – ultimately building brand equity.

***Keywords***— Branding, brand equity, cannabis, organisational stigma

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# Clinical Utility of Quantitative-EEG / Neurofeedback in Diagnosis of ADHD Children

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**Introduction**: ADHD is the most common neurodevelopmental disorder of childhood, that significantly affect the well-being, social interactions and academic achievement of children. Its prevalence is Worldwide, 4% (range 3-11%). In Alexandria, Egypt it is 6% (4-8%) in 2013. ADHD can lead to\: educational attainment, social functioning, substance addiction, comorbid anxiety or depression and anti-social personality . Diagnosis depends on personnel observation with parent questionnaire as using DSM 5 criteria and Conner's Comprehensive Behavior Rating Scales.

**Aim** : The clinical utility of QEEG/neurofeedback (NFB)in ADHD diagnosis and its classification

**Subjects**: This study was carried out on 80 children . Their ages were between 6 and 15 years old . Children were categorized as follows:

Group I: 60 newly diagnosed children with ADHD, not yet on treatment

Group II: 20 healthy children of matching age, sex and social class from general population as control.

**Methods:** All the children were subjected to the following:

IQ testing using Stanford-Benet scale (5th edition ,Arabic version5)

Diagnosis of ADHD depending on:

1. DSM-5 criteria .

2.Conner rating scale for ADHD (Arabic version)

QEEG was done for all cases. Brainwaves Speed are measured in Hertz. The cases were fitted with a 19-electrodes caps according to standard 10–20 international QEEG configuration

CLASSIC EEG BANDS :

Delta band (0–4 Hz) : low sleepy brain condition

Theta band (>4–8 Hz): Present during pre-sleep or **trance state**

Alpha band (>8–12 Hz): resting and relaxation all over arousal

Beta band (>12–35 Hz): divided into:

low frequency(LF >12–20 Hz) during concentration

high frequency(HF >20–35 Hz)during emotional stress and tens

The chosen brain regions for ADHD assessment by using QEEG/NEUROFEEDBACK NFB were

Cz: FOR ATTENTION AND CONCENTRATION

C3: for impulsivity/hyperactivity

Results

❖ there were no significant differences between ADHD according to average amplitude of power spectrum of Alpha, Delta band at all brain regions,

❖ Theta : it was **statistically significant low** of average amplitude of power spectrum of Theta band at level $\geq$30.95, there was a 50% sensitivity and 65% specificity for ADHD (p<0.001).

❖ Beta LF : **it was statistically significant high** that average amplitude of power spectrum of beta low frequency band at level <1.25, there was a 63% sensitivity and 95% specificity for ADHD (p<0.001).

❖ Beta LF/ theta ratio BTR: **There were significant differences** between ADHD cases & control according to average amplitude of power spectrum of Theta/Beta LF ratio at all brain regions

❖ ( Beta LF /theta +betal LF ) % whereas normal is > 55 %: it was statistically significant less than 55% at level $\geq$13.65, there was a 83.33% sensitivity and 90% specificity for ADHD (p<0.001).

**Conclusion:**

1. Children with ADHD have QEEG/neurofeedback dysfunctions (abnormal low % of beta LF/theta over regions of attention and concentration (Cz) and \impulsivity/hyperkinesia (C3) that underlie their symptomatology. Proving it as a useful method aiding the diagnosis of ADHD children.

2. QEEEG/NFB over Cz and C3 could be used for subclasssification of ADHD

3. QEEG /NFB over Cz and C3 can be used not only for ADHD diagnosis but also for sessions and follow up of treatment efficacy

# Executive Function Assessment with Aboriginal Australians

Keiller. T, Hindman. E, Hassmen. P, Radford. K & Lavrencic. L

*Abstract—*

**Background:** Psychosocial disadvantage is associated with impaired cognitive abilities, with executive functioning (EF) abilities particularly vulnerable. EF abilities strongly predict general daily functioning, educational and career prospects, and health choices. Reliable and valid assessment of EF is important to support appropriate care and intervention strategies. However, evidence-based EF assessment tools for use with Aboriginal Australians are limited.

**Aim and Method:** This research aims to develop and validate a culturally appropriate EF tool for use with Indigenous Australians. To this end, Study One aims to review current literature examining benefits and disadvantages of current EF assessment tools for use with Indigenous Australians. Study Two aims to collate expert opinion on the strengths and weaknesses of various current EF assessment tools for use with Indigenous Australians using Delphi methodology with experienced psychologists ($n = 10$). The initial two studies will inform the development of a culturally appropriate assessment tool. Study Three aims to evaluate the psychometric properties of the tool with an Indigenous sample living in the New South Wales Mid-North Coast. The study aims to quantify the predictive validity of this tool via comparison to functionality predictors and neuropsychological assessment scores. Study Four aims to collect qualitative data surrounding the feasibility and acceptability of the tool among Indigenous Australians and health professionals.

**Expected Results:** Findings from this research are likely to inform cognitive assessment practices and tool selection for health professionals conducting cognitive assessments with Indigenous Australians. Improved assessment of EF will inform appropriate care and intervention strategies for individuals with EF deficits.

*Keywords—* Aboriginal Australians, assessment tool, cognition, executive functioning.

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# Immunoglobulin G Glycosylation Profile in Influenza and COVID-19 Infected Patients

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**Abstract**— Immunoglobulin G has essential role in defense against infectious diseases, but its role cannot be fully recognized without understanding of changes in its N-glycans attached to the Fc domain. We analyzed and compared total IgG glycome in plasma samples of patients with influenza, patients with COVID-19 and healthy controls. We found similarities in IgG glycosylation changes in COVID-19 survivors and influenza patients that could be the consequence of adequate immune response to enveloped viruses, while observed changes in deceased COVID-19 patients may indicate its deviation.

**Keywords**— COVID-19, glycosylation, immunoglobulin G, influenza, pneumonia, viral infection.

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# Clinically-Based Improvement Project Focused on Reducing Risks Associated with Diabetes Insipidus, Syndrome of Inappropriate ADH, and Cerebral Salt Wasting in Paediatric Post-Neurosurgical and Traumatic Brain Injury Patients

Shreya Saxena, Felix Miller-Molloy, Phillipa Bowen, Greg Fellows, Elizabeth Bowen

**ABSTRACT:**
Fluid balance complications are well-established post-neurosurgery and traumatic brain injury (TBI). The triple-phase response requires fluid management strategies reactive to urine output and sodium homeostasis as patients shift between Diabetes Insipidus (DI) and Syndrome of Inappropriate ADH (SIADH). To improve clinical care for these complex patients, an audit of existing institutional guidelines was undertaken. New guidelines were developed with structured educational packages for the specialist teams involved, and subsequent assessments were conducted of their impact. Two periods were audited using set standards before and after changes were implemented. Data was collected from the CQUIN neurosurgical database and electronic medical records; all paediatric patients post posterior fossa (PFT) or supratentorial surgery or with a TBI were included. A literature review of evidence-based practice, initial audit data, and stakeholder feedback was used to develop new clinical guidelines and nursing standard operation procedures.
Results: Audit-1 January2017-June2018, n=80; Audit-2 January2020-June2021, n=30 (reduced operative capacity due to COVID-19 pandemic). All patients were managed within a high dependency setting, with 26-33% initially in paediatric intensive care. Step-down was to neurosurgical/neurorehabilitation wards. Overall, improvements in both clinical fluid balance and biochemical monitoring were demonstrated. The number of clear fluid management plans documented postoperatively increased, leading to early recognition and management of evolving fluid-balance abnormalities. The endocrine team was involved earlier and in all complex cases. However, significant Na fluctuations (>12mmol in 24 hours) remained similar – 5 vs. 6 patients – (complex pituitary-hypothalamic pathology and TBI), and recommended adaptive fluid management strategy was not always used.
Conclusions: Revised clinical guidelines using audited data, evidence-based literature review, and stakeholder consultations have been adopted with effective change. Patient safety improved through effective post-neurosurgical fluid management and multi-disciplinary team working.

**Table:**

| Standard: | Audit-1 | Audit-2 | | Fishers |
|---|---|---|---|---|
| Complete fluid balance charts | 51% 40/79 | 77% 13/17 | | 0.063 |
| Fluid management plan post-op | 64% 52/81 | 71% 12/17 | | 0.7813 |
| Electrolytes post-op | 78% 62/79 | 94% 16/17 | | 0.1816 |
| Electrolytes 4-8hrly | 18% 14/78 | 35% 6/17 | | 0.1848 |
| Endocrine team Involvement | 14% 11/78 | 35% 6/17 | | 0.0735 |
| DDAVP prescription with endocrine team | 70% 3.5/5 | 100% 4/4 | | 0.444 |

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**Category**: Poster Presentation

# Drug Resistance among Women Attending Clinics in the Upper Region of Ghana

Philip Enyan, Josephine Sasraku, Opoku Joseph, Emmanuel Sowah

*Abstract—*

**Background:**

Initial evidence from resource-limited countries using the WHO HIV drug resistance (HIVDR) threshold survey suggests that transmission of drug-resistance strains is likely to be limited. However, as access to ART is expanded, increased emergence of HIVDR is feared as a potential consequence. We have performed a surveillance survey of transmitted HIVDR among recently infected persons in the geographic setting of Accra, Ghana.

**Methods:**

As part of a cross-sectional survey, 2 large voluntary counseling and testing centers in Accra enrolled 50 newly HIV-diagnosed, antiretroviral drug-naïve adults aged 18 to 25 years. Virus from plasma samples with >1,000 HIV RNA copies/mL (Roche Amplicor v1.5) were sequenced in the pol gene. Transmitted drug resistance-associated mutations (TDRM) were identified according to the WHO 2009 Surveillance DRM list, using Stanford CPR tool (v 5.0 beta). Phylogenetic relationships of the newly characterized viruses were estimated by comparison with HIV-1 reference sequences from the Los Alamos database, by using the ClustalW alignment program implemented .

**Results:**

Subtypes were predominantly D (39/70, 55.7%), A (29/70, 41.4%), and C (2/70; 2, 9%). Seven nucleotide sequences harbored a major TDRM (3 NNRTI, 3 NRTI, and 1 PI- associated mutation); HIVDR point prevalence was 10.0% (95%CI 4.1% to 19.5%). The identified TDRM were D67G (1.3%), L210W (2.6%); G190A (1.3%); G190S (1.3%); K101E (1.3%), and N88D (1.3%) for PI.

**Conclusions:**

In Accra the capital city of Ghana, we found a rate of transmitted HIVDR, which, according to the WHO threshold survey method, falls into the moderate (5 to 15%) category. This is a considerable increase compared to the rate of <5% estimated in the 2006-7 survey among women attending an antenatal clinic in mamobi. As ART programs expand throughout Africa, incident infections should be monitored for the presence of transmitted drug resistance in order to guide ART regimen policies.

**Abstract Summary**

Resource-limited countries using the WHO HIV drug resistance threshold survey suggests that transmission of drug-resistance strains is likely to be limited. However, ART is expanded, increased emergencies of HIVDR is feared as a potential consequence. We have performed a surveillance survey of transmitted HIV among recently infected persons in Ghana.

*Keywords—* Drug,Resistance, Virus, Medications.

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# Gender Differences in Extending Working Lives among Indian Elderly: Role of Health

Priya Maurya

***Abstract***— This study explores whether gender differences in workforce participation can be attributed to socioeconomic status, emphasizing health conditions among Indian elderly. LASI data were utilized and multivariate analysis have been done. Work participation was higher among elderly with depression only health condition for both men and women. It was found that odds of being in the workforce among men and women with physical health condition was lower than with no health conditions.

***Keywords***— ageing, gender, physical health, depression, work participation.

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# Fucoidan Extract a Major Part of Nutrition and Health

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## Abstract

Kelp a term referred to seaweeds are divided into three groups, and the brown algae is a common and largest subgroup used for food. Fucoidan can be obtained from various species of brown algae, it is a rather heterogeneous group of sulfated polysaccharides with a complex and heterogeneous structure, lacking uniformity, and has a high nutritional value and health benefits when consumed (Wijesinghe and Joen, 2011; Sanjeewa et al.,2016). The purpose of this review is to discuss the properties, structure, and nutraceutical benefits of fucoidan extract as molecular weight has been shown to play a significant role in the biological activity of polysaccharides.

Nonetheless, aggregate bioactive possibilities about sulfated polysaccharides (SPs) require their essential natural sources in potential mechanical applications. Consequently, accentuation is given to audit the accessible, logical writing regarding the bioactive properties of SPs isolated from class Sargassum with their potential biomedical applications to use this valuable natural asset for people in the future (Zoysa et al., 2007). The Fucoidan detached from kelp is known to be an anti-cancer solid specialist. Moreover, they are more intense against significant human diseases like diabetes, Alzheimer's disease, Parkinson's disease, and AIDS (Pangestuti et al., 2011; Yende et al., 2014; Barbosa et al., 2014).

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# A Multidisciplinary Investigation of the Musculoskeletal Health Benefits of Tennis

Omid Khaiyat, Denise Roche, Farzad Amirabdollahian, Stefan Koehn, Matthew Jackson

***Abstract—*** The present study investigated impact of regular tennis participation in enhancing Musculoskeletal (MSK) function in 90 participants (tennis players & nonplayers). MSK function was assessed by cluster analysis of electromyographic fatigability, isometric strength, ; and body composition (bioelectrical impedance analysis). The findings suggest tennis as an excellent activity mode to promote MSK health and a viable alternative to existing physical activity guidelines.

***Keywords—*** tennis, musculoskletal health, cluster analysis, physical activity.

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# The Impact of Vibration as an Exercise Modality on Shoulder Girdle Muscle Activation and Timing

Omid Khaiyat, David Hawkes, Ian Horsley

***Abstract*—** EMG recorded from 15 shoulder girdle muscles. Isometric shoulder flexion at 25% maximal voluntary contraction was performed in three testing scenarios [no vibration; whole body vibration (WBV); and arm vibration (AV)] in 20 healhy partcipants. A press up and triceps dips with and without vibration were also performed. The results indicate that use of vibration as an adjunct to exercise provokes a near global increase in shoulder muscle activation.

***Keywords*—** EMG, shoulder, vibration, muscle activity, exercise.

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# An Electromyographic Study of Muscle Coordination during Dynamic Glenohumeral Joint Elevation

Omid Khaiyat, David Hawkes

***Abstract***— Introduction: There remains a lack of information on sophisticated coordination patterns across shoulder girdle muscles. Considering the stability of the shoulder being heavily dependent on coordinated muscle activity during its wide-ranging movements, it is important that key intermuscular relationships are well-defined for a better understanding of underlying pathology. This study investigated shoulder intermuscular coordination during different planes of shoulder elevation. Materials and Methods: EMG was recorded from 14 shoulder muscles in 20 healthy participants during shoulder flexion, scapula plane elevation, abduction, and extension. Cross-correlation by means of Pearson Correlation Coefficient (PCC) was used to examine the coordination between different muscles and muscle groups. Results: Coordination between rotator cuff and deltoid muscle groups was significantly higher (p =0.020-0.035) during the initial (PCC) = 0.79) and final (PCC = 0.74) phases of elevation compared to the mid-range (PCC = 0.34). Furthermore, a high level of coordination (PCC = 0.89) was noted between the deltoid group and the adductor group (latissimus dorsi and teres major) during the initial stage of shoulder elevation. Conclusion: The destabilising force of the deltoid during the initial stage of shoulder elevation is balanced by coordinated activity of rotator cuff, latissimus dorsi, and teres major. This is also the case for the end-range of movement, where increased demand for stability again leads to higher coordination between the deltoid and rotator cuff muscle groups. Appreciation of the sophistication of normal shoulder function evidence-based rehabilitation strategies for conditions such as subacromial impingement syndrome or shoulder instability can be developed.

***Keywords***— shoulder, coordination, EMG, muscle activity, upper limb.

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# Sport-Related Affective Benefits for Teenagers Are Getting Greater as They Approach Adulthood: A Large-Scale French Investigation

Annie Carton, Alexis Barbry, Jérémy Coquart, Hervé Ovigneur, Camille Amoura, Gabor Orosz

***Abstract***— The present investigation examined how sports club membership is related to adolescents' daily negative and positive affects as they age. Robust prior results demonstrated that sports club membership is positively related to positive affect and negatively related to negative affect. However, surprisingly, no prior studies examined whether these benefits are consistently present throughout the teenage years or there are certain critical periods when teenagers can affectively profit more from being members of a sports club. The present cross-sectional investigation examined these questions on a comprehensive sample of French adolescents (N=17,337, female=7,604, aged between 10 and 18, Mage=12.45years, SDage=1.94years). Besides the expected affective benefits of a sports club membership, there was no interaction between age and negative affect. However, late adolescents reported greater daily positive affective benefits of sports club membership than early adolescents. These results suggest that late adolescents can use the extra affective benefits of sports club membership to gain advantages for the first steps of their adult life, such as coping with career start or transition to higher education. These results can provide guidelines for future studies to prioritize late adolescents with heightened positive sport-related affective benefits. It can also be useful information to promote sport among late adolescents.

***Keywords***— adolescents,positive affect,sports club membership,positive psychology,broaden-and-build,physical activity.

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# Is Football or Badminton Associated with More Positive Affect? The Links Between Affects and Sports Club Membership Among French adolescents

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**Abstract**
Prior studies extensively examined the way sports club membership can lead to beneficial affective outcomes. Prior experiments also found that team sports, intensive sports, and sports that are frequently pursued can lead to even more affective benefits. However, no prior studies examined the differences between the affective benefits of specific      sports. Based on prior results, we supposed that certain sports that meet all the previously set criteria—will provide the greatest affective benefits. The present large-scale investigation examined the data of adolescents (N=12,849, female=5,812, aged between 10 and 18, $M_{age}$=12.56 years, $SD_{age}$=2.00) and aimed to fill this gap. Firstly, the results showed that—although differences in affect can be found between the lack of club membership and most of the sports club memberships—the differences between the specific sports are less striking. Secondly, the sports that are associated

with the highest level of positive and the lowest level of negative affectivity are not necessarily the ones expected.      Finally, adolescents who practice athletics, reported the lowest means of negative, and the highest means of positive affect. However, it did not differ significantly from the results regarding the most practiced sport in France: soccer. Our results suggest that, soccer as the most practice sport among French adolescents, was associated with more positive affects than the majority of the 10 most licensed members French sports practiced by teens between 2008 and 2019.      All in all, being a member of a sports club is associated with affective benefits, and some specific      sports clubs can have some extra benefits.

***Keywords*:** Adolescents; Negative affect; Positive; Sports club membership

## 1. Introduction

As a parent or as an adolescent, the question might arise: what specific sports club membership might be related to the most  positive affect ? Surprisingly, we have had limited information to give clear answers to this question. The present work uses a large French database and aims to provide some tips to answer them.

The positive effect of physical activity on the mental health of adolescents is unquestionable (Biddle & Asare, 2011; Donnelly et al., 2016). For example, a recent meta-analysis (Donnelly et al., 2016) found that physical activity has a positive impact on children's cognitive functioning and it also has a positive effect on the development of some areas of the brain such as the hippocampus (Gomez-Pinilla & Hillman, 2013), the prefrontal cortices (Kopp, 2012) or the even more specific regions of the basal ganglia (Chaddock et al., 2010, 2012) which can boost complex cognitive processes. Moreover, physical activity can not only have an immediate positive effect on the brain; if it is practiced in adolescence, it can have long-lasting positive consequences. For example, it can serve as a predictor for the level of physical activity later in adulthood (Telama et al., 2005), a metric associated with better well-being (Abdin et al., 2018). All in all, promoting physical activity in adolescence can have cognitive benefits and can boost practicing health-enhancing behaviors in adulthood.

In the present paper, the term affective benefit is based on Bratman et al.'s work (2021) and refers to (a) more positive affect and (b) a less negative affect as the consequence of belonging to a sports club. Besides the long-lasting cognitive benefits, meta-analyses robustly demonstrate the affective benefits of physical activities among adults and adolescents (Biddle & Asare, 2011; Bourke et al., 2021; Janssen & Leblanc, 2010; Marquez et al., 2020; Rodriguez-Ayllon et al., 2019; Wiese et al., 2017). These recent works show that engaging in physical activities or doing sports can lead to elevated positive affectivity such as positive subjective experiences or positive mood, *e.g.* joy, interest, and alertness (Miller, 2011). It can also reduce negative affectivity (Zhang et al., 2020).

*Characteristics of physical activities and affective benefits*

Both physical and *sports activities* (referring to physical effort guided by specific rules, very often pursued competitively) appear to be associated with physical and mental health benefits. These benefits include affective consequences, better well-being and better quality of life compared to other forms of leisure-time physical activities in adolescence (Eime et al., 2013). Moreover, participation in *organized sports* can have further benefits as it supports social belonging and bonding between members (Eime et al., 2013). For example, Brettschneider (2001) found that participating in organized sport (as a member of a sports club) did not only have a positive effect on adolescents' self-esteem but it also contributed to the development of their social competence (Howie et al., 2010). Sports activities are not an encapsulated in all adolescents' life. Gisladottir et al. (2013) found that those adolescents who were members of a sports club had stronger beliefs in performing well at school compared to their peers who did not practice sports in a club.

Organized sports have various subcategories, and prior scientific investigations focused on their different affective benefits. Pluhar et al. (2019) found that people practicing *team sports* (soccer, football and hockey) reported less anxiety and depression compared to those who practiced *individual sports* (running, gymnastics and diving). Robust results (Guddal et al., 2019) suggest that the mental health benefits of team sports are related to the social aspects such as social belonging and being part of a team (*e.g.*, Eime et al., 2013).

Another categorization of organized sports is related to the *aesthetic characteristics* of the different sports. Davison et al. (2002) compared the aesthetic sports (swimming, dance, gymnastics, aerobics, cheerleading, baton twirling, and figure skating) versus the non-aesthetic sports (team sport, athletics, tennis and martial arts) and found that practicers of aesthetic sports are more at risk to have concerns about their weight, which is associated with negative emotions (Augestad & Flanders, 2002; Espeset et al., 2012; Tan et al., 2016).

A third classification of organized sports is related to the *place of practice* (Thompson Coon et al., 2011). Solid evidence suggests that practicing physical activity in an outdoor environment was associated with a decrease in anger, anxiety and depression and with an increase of energy, revitalization and positive engagement (Lawton et al., 2017; Pasanen et al., 2018; Thompson Coon et al., 2011). Thus, team and non-aesthetic sports and also practicing physical activity in a natural environment seem to be associated with less negative and more positive ones. However, the information about the impact of a specific sport on negative and positive affects throughout adolescence is lacking.

A fourth classification is related to the *intensity* of organized sports that can impact both negative and positive affectivity (Costigan et al., 2019; Howie et al., 2020).[1] In their definition of physical activity, the World Health Organization defines three levels of intensity activities can be pursued at: low, moderate and vigorous. Earlier studies showed that all intensity levels had certain affective benefits (Ekkekakis, 2003; Ekkekakis et al., 2000). However, more recent studies (Costigan et al., 2019; Howie et al., 2020; Qin et al., 2020) suggested that vigorous

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[1] We have to mention that it is not only related to organized sports, but any sort of physical activities.

physical activity is associated with more robust psychological benefits compared to low physical activity. For example, Howie et al. (2020) found that participating at moderate or vigorous physical activities was associated with a more favorable mental health profile. Costigan et al. (2019) found that only vigorous physical activity was associated with well-being among adolescents. Besides intensity, two related aspects can also have positive consequences: higher *frequency of practice* (Hassmén et al., 2000; Jiang et al., 2021) and the higher *volume of physical activity* (Bell et al., 2019; Sagatun et al., 2007) both lead to better affective benefits.[2]

*The present study*

One can suppose that if adolescents can harvest the affective benefits of doing sports, they will 134  be motivated to engage more in sports to enjoy the life-long positive consequences. Therefore, 135  it is important to know what type of sports might be associated with the strongest positive 136  affects and least frequently with negative ones. Based on the above-mentioned studies, we 137  expected that sports club membership in general will have a robust affective benefit compared 138  to the lack of membership. However, we also expected that membership of a club for a 139  collective, non-aesthetic, outdoor and vigorous sport will lead to the most salient affective 140  benefits. It seems unlikely that a single sport will fulfill all of these criteria. However, some 141  sports could meet most of them e.g. soccer, athletics, and basketball. In contrast, gymnastics, 142  dance or horse riding meet the least of these criteria.

## 2. Methods

### *Procedure and Participants*

This study was conducted in accordance with the Declaration of Helsinki and with the approval of the National Ethics Committee Board (n°00012476-2021-28-05-109). Participants for this study were recruited through the project of the so-called "*French Physical and Mental Health Inventory*" program. Besides the National Ethics Committee permission, the data gathering, and its further use was approved by the National Commission on Informatics and Liberty (RF 1232206). As the respondents were minors, written and signed informed consents were obtained from their parents. Potential respondents of the survey were informed about the content of the research and they were requested to indicate their intention to participate (they provided an assent).

The dataset was part of an extensive multi-year, cross-sectional data gathering. For the present paper we only focus on the data of adolescents between 10 and 18 years of age. Adolescents needed to state whether they are members of a sports club or not. We have selected the

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[2] Hassmén et al. (2000) found that practicing regular physical activity (two to three times a week) decreased negative affect (depression, anger and stress) but also increased well-being compared to practicing less frequently. Moreover, in a recent study, Jiang et al. (2021) found that children and adolescents who practiced training sessions three to five times per week have a better mental health compared to those who practice only once a week. A strongly-related element to take into account to impact the adolescents' affect is the *volume of physical activity* (Bell et al., 2019; Sagatun et al., 2007). Indeed, increasing the volume of physical activity might be a key element of protection against emotional problems during adolescence (Bell et al., 2019).

adolescents who are not involved in a sports club and those who are members of a club for the most practiced sport (*i.e.* at least 240 adolescents per sport). We found this step important for avoiding extreme means as the result of a few biased respondents. Although the present sample is comprehensive, it was not representative for French adolescents. It was recruited between 2008 and 2019, consisted of 12,849 adolescents (5,812 females, 45.23%) who were aged between 10 and 18 years (*M*=12.56, *SD*=2.00). Most of them, 78.53% reported that they belong to a sports club, and approximately one fifth of the participants did not belong to a one.

### *Measures*

**Positive and negative affects**. The survey was administered approximately 30 minutes after a physical fitness evaluation in school, in a classroom environment. Among other measures, participants were requested to describe the extent they experienced a set of positive and negative emotions in the past three or four days. Seven adjectives described negative affects (angry, sad, anxious, ashamed, guilty, annoyed, and worried), and five described positive ones (joyful, enthusiastic, proud, full-of-energy, happy). Responses were provided on a five-point Likert-scale ranging from 1 (not at all) to 5 (very much). This questionnaire has been recently used by Carton et al. (2021). We supposed that the 12 items belong to two factors. A confirmatory factor analysis (performed with R, package lavaan) was conducted with two first-ordered factors, with robust maximum likelihood estimator (MLR) supported this notion with acceptable model fit indices (CFI=0.941, TLI=0.927, RMSEA=0.064, $CI_{95\%}$=0.062-0.066, SRMR=0.039). Although these values are not perfect, they are acceptable based on the seminal work of Hu & Bentler (1999) and Marsh et al. (2005). Both the positive (α=0.85) and negative scales (α=0.79) have excellent internal consistency values.

**Sports club membership**. Before the measurements of physical fitness level and after the measurements of height and body mass, the participants responded to the following question: "Are you a member of a sports club?". The participants who answered positively to this question, were asked to report the sport they practiced most regularly.

### 3. Results

### *Analytic strategy*

The normality of the distribution was verified with a Shapiro-Wilk test, and equality of variances was analyzed with Levene's test. One-way ANOVA with Benjamini-Hochberg post-hoc test was conducted to determine differences in positive and negative affects related to the different sports. This method uses a modified version of the Bonferroni correction for a high number of hypothesis testing. As in the present case controlling for the false discovery rate was more important than the conservative control of familywise error rate, this post-hoc approach appeared adequate (Benjamini & Hochberg, 1995). Based on the recommendations and prior studies, this post-hoc method is strongly recommended if the number of tests is high and it is broadly used in numerous recent studies that conducted similar, large-scale multiple comparisons (Hopkins et al., 2020; Maroun et al., 2021; Nakajima et al., 2019).

### *Negative Affect Differences Along Sport Club Membership*

ANOVA post-hoc analyses demonstrated differences between 44.9% of the comparisons of the sport club memberships that French teens frequently mentioned. Teens practicing martials arts,  athletics, basketball, soccer, gymnastics, swimming, and volleyball reported significantly  lower levels of negative affects compared to their peers without a sports club membership.      We would like to highlight only a few examples of the inter-sport differences. For example,   teens who practice boxing  reported more negative affect compared to those who practice   athletics, volleyball, gymnastics, martial arts, soccer, basket, swimming, dance, horse riding,  and handball. Badminton club members and those teens who do not belong to any sports club  reported more negative affect compared to those who practice athletics, martial arts, basketball,   soccer, gymnastics, and volleyball. However, teens who practice athletics, gymnastics, soccer,   and volleyball reported less negative affect compared to those who  practice badminton, boxing,   handball or to those who did not practice in a sports club. See Table 1 and  figure 1 for details   about differences in negative affects.

### *Positive Affect Differences Along Sport Club Membership*

ANOVA post-hoc analyses demonstrated differences between 47,4% of the comparisons of the sports club memberships French teens frequently mentioned. Teens without a sports club membership reported significantly lower levels of positive affects compared to teens with the following ten sports club memberships: martial arts, athletics, basketball, boxing, dance,  soccer, gymnastics, handball, swimming, and volleyball.      We would like to highlight only
a few examples of the inter-sport differences. For example, teens who practice athletics  reported more positive affect compared to those who practice badminton, basketball, boxing,  dance, horse riding, handball, swimming, or to those teens who do not belong to any sports   club.
Soccer club members reported more positive affect compared to those who practice  badminton, boxing, dance, horse riding, handball, swimming, and to those who do not belong    to any sports club. However, teens who practice badminton, dance, horse riding and those  who do not belong to any sports club reported less positive affect compared to those who   practice athletics, soccer, volleyball and martial arts. See table 2 and figure 1 for details of  differences in positive affects.

### 4. Discussion

What specific sport might be associated with the highest level of positive and the lowest level of negative affects ?        First of all, in line with robust prior findings most of the      sports appear to have affective benefits. Secondly, the differences between these benefits are not huge and they are mostly consistent with prior findings that focused on sport characteristics as team *vs.* individual, aesthetic *vs.* non-aesthetic, indoors *vs.* outdoors and low *vs.* high intensity. However, there are some nuances, limitations and questions that might be worth discussing.

### *Sports club participation*

In a recent article, Carton et al. (2021) found that adolescents who are members of sports clubs reported more positive affects and less negative ones compared to their peers who do not belong to a sports club. The utilized affect measure is described in details in Carton et al., (2021). Practicing sports has two direct effects on the individual's mood: (a) a general improvement in the mood right after a training session, and (b) a decrease in negative emotional states, such as anxiety, irritability, and guilt (Iacolino et al., 2017). However, there are potential indirect effects, as well. For example, Putnam (2000) used a sociological perspective to point out the reasons why bowling alone is much less beneficial than doing it in the company of acquaintances. Being part of sports clubs, can provide not only great opportunities to build weak links (*i.e.*, less intimate, less in-depth relationships with the opportunity of networking), but it can also build strong links as the result of years-long friendships strengthened under stressful and exciting situations (*e.g.*, Granovetter, 1973). These clubs can provide opportunities for adolescents to build, extend and reinforce their social network (Howie et al., 2010); satisfy their need to belong (Baumeister & Leary, 1995; Walton & Brady, 2020), raise their self-esteem and strengthen their social skills (Brettschneider, 2001). All of these factors can play a role in the well-known fact that adolescents who belong to a sports club experience more positive and less negative emotions (Brettschneider, 2001; Gisladottir et al., 2013; Howie et al., 2010). One might think that it does not matter what kind of sports club a teen belongs to. The present study demonstrated that it is not the case, and there are some small, but measurable differences between the benefits of pursuing different sports.

### *Sports with more affective benefits than others: Athletics*

All in all, the differences between the benefits of different sports were not large (never reaching d=0.5), but some of them appeared to be more beneficial than others.     In the following, we will examine one sport in detail that appears to have one of the greatest affective benefits: athletics. It is often considered as one of the oldest sports, tracking back to ancient Greece (776 BC). At that time athletes were considered idols who master the harmony of body and mind (Jaeger, 1988). Adolescents belonging to an athletics club reported the highest positive and lowest negative affects among the examined groups. Although, the mean affects did not differ from other sports significantly. Athletics (also called Track and Field) is a comprehensive collection of specific sports offering a repertoire of different practices (*e.g.*, races, jumps, throws). The current affective results are somewhat surprising as it is an individual sport, and prior studies suggest that team sports lead to more psychological benefits compared to individual sports (Guddal et al., 2019; Pluhar et al., 2019). Despite athletic sports being individual *per se*, the value of collectivity and the team is especially important at a club level. In line with the literature, athletics are practiced outdoors and have the extra affective benefits compared to indoors sports (Lawton et al., 2011; Pasanen et al., 2018; Thompson Coon et al., 2011). They are also often considered sports requiring vigorous physical activity that has an additional affective benefit (Costigan et al., 2019; Howie et al., 2020; Qin et al., 2020). Teens in athletics clubs participate in competitions which reflect a high level of motivation (Gernigon, 1998), contributing to positive affects (Pekrun et al., 2002). To perform well in athletics, frequent and regular practice (at least three training sessions per week) is required, also adding

a tremendous amount of well-being benefits (Hassmén et al., 2000). Athletics appears to accumulate multiple sources of affective benefits such as the possibility to autonomously choose achievement goals; regular, frequent, and intense practice; and an outdoor environment. We can hardly find this constellation with other types of sports.

### *Sports with more affective benefits than others: Soccer*

Our results also suggested that adolescents who practice soccer also experience greater affective benefits compared to other sports. This result is in line with prior studies that found team sports lead to extra affective benefits compared to individual sports (Guddal et al., 2019; Pluhar et al., 2019). Moreover, soccer is very often considered as a vigorous physical activity with a frequent aerobic intermittent exercises (Fernandes et al., 2015). Soccer is very practice among teen boys in France (Ministère de la Jeunesse des Sports et de la Vie associative et al., 2018). Furthermore, during adolescence, boys might have more positive affects and less negative ones compared to girls (Pascual et al., 2012). The popularity of soccer is unquestionable in France with its 2 million soccer club players today. There are one million matches played each year and tens of thousands of clubs (Ministère de la ville de la jeunesse et des sports, 2015). For these millions of players, playing soccer can provide a great opportunity to experience both positive and negative emotions, gather collective and individual experiences, and be part of just and unjust processes that can serve as a basis of recognition and disregard (Nuytens, 2011). The soccer club can strengthen the sense of social belonging in the local community and can provide various social resources (Retière, 2003). Finally, we might acknowledge that soccer can also provide room for strong identification with the famous French national team and with the very popular local teams. Soccer is also an outdoor sport which is a predictor of beneficial affective outcomes (Lawton et al., 2017; Pasanen et al., 2018; Thompson Coon et al., 2011).

To a certain extent, the present results might also contribute to the explanation of why soccer is the most popular sport in France (Ministère de la Jeunesse des Sports et de la Vie associative et al., 2018). Soccer could be considered a mass sport (Ohl, 2004), and based on the present results, being a member of a soccer club is associated with positive affects. All in all, it appears that for an adolescent being part of a soccer club in France does not only provide some odds to reach the highest performance in this sport (France is very often among the best teams in the world), but it could also be related to a great deal of positive affective benefits. Our results concerning the sports with more affective benefits (*i.e.,* athletics and soccer) can be explained by including various factors from several theoretical fields with particular emphasis on psycho-social aspects, developmental and physiological approaches but more studies are needed to confirm and fully explain our results.

### *Sports with less affective benefits*

Every sports club membership is associated with some level of affective benefits, as previously established. However, according to the present results, some sports seem to present somewhat less affective benefits. Our results suggest that adolescents, who practice badminton, boxing, horse riding or dance as members of a sports club reported the least positive and the

most negative affects. Prior studies can provide some hints why these sports might be associated with less affective benefits. Badminton, boxing and dance are indoor sports which might lead to less affective benefits (Lawton et al., 2017). Badminton is a zero sum, open-skill sports in which players need to adapt their actions to quickly changing and relatively unpredictable conditions (Di Russo et al., 2010). Boxing requires inter-individual confrontation (Ministère de l'Education Nationale et de la Jeunesse, 2019) involving punches that lead to not only physical pain, but negative emotions such as anger or fear (Lecroisey, 2017). Boxers often experience intense negative mood the results of harsh dietary strategies to lose weight before competition (Hall & Lane, 2001; Lane & Terry, 1996). Martial arts are different from boxing as they are rooted in the local culture roots and most of them put emphasis on serenity and calm (Fournier, 2000). Dance as an aesthetic sport might be linked with an increase level of weight concern (Davison et al., 2002), and this weight concern might be associated with the more negative emotions (Augestad& Flanders, 2002; Espeset et al., 2012; Tan et al., 2016). Furthermore, three-quarter of the adolescent members of dance clubs are girls, who tend to report more negative emotions and less positive ones compared to their boy peers (Ministère des Sports, 2002; Pascual et al., 2012). Although these guesses are based on prior literature, further research is required to explain these sports club-related differences among adolescents.

### *Limitations*

This study has some limitations. First, regarding every single student, affects were surveyed 30 minutes after a physical fitness assessment that could possibly—although homogenously—influence the retrieval of respondents' affects regarding the previous few days. Adolescents could only indicate one sports club membership. If they belonged to multiple clubs simultaneously, they were requested to indicate the one they spent more time practicing with. Next time, we might provide room to indicate multiple memberships to have a deeper understanding of the cumulative effects of sports club membership. Furthermore, as the goal was keeping the survey as short as possible, we did not have an opportunity to assess the perceived intensity, frequency and volume of the practiced sport. Although our affect measure showed consistent factor structure and great internal consistency. Other, more broadly validated tools could have been used in the current study such as the PANAS (Watson et al., 1988). Future work might either use a more commonly utilized measure or it is also possible to validate this measure. It is also possible that future studies might try to use ecological momentary assessment (Trull & Ebner-Priemer, 2013) if they are interested in short term and less pervasive benefits. As it was a cross-sectional survey study, we do not know anything about causality. Therefore, it is entirely possible that the findings are due to self-selective bias: namely, that teens with a more positive disposition tend to choose athletics or soccer; and that it is not necessarily athletics or soccer that will lead to an increase in positive affects and a decrease in negative affects. Causality can only be investigated through longitudinal studies and future experimental work.. Despite we aimed to choose only those sports that were practiced by many adolescents, we can mention another limit of this study regarding the unequal number of adolescents in the different groups.

## 5. Conclusion

Our study suggests that being a member of a sports club is associated with affective benefits for teenagers. However, it appears that athletics and soccer club membership might be associated with the highest levels of affective benefits whereas boxing, badminton, dance or horse-riding club memberships are associated with less benefits. The present one is a pioneering, large-scale study that might provide broader guidelines for future scientific investigations in this field. However, it is without establishing a unidirectional causal link stating that certain sports club membership lead to more affective benefits than others.

**Contribution to the field statement**

Prior studies extensively examined the way sports can lead to positive affective outcomes. Other experiments also found that team sports, intensive sports, and sports that are frequently pursued can lead to even more affective benefits. However, no studies examined the differences between the affective benefits of specific     sports. The present study aims to fill this gap and with a large-scale French adolescent data (N=12,849) demonstrated that the affective benefits associated with different sports club memberships are not completely homogenous and there are sports that are associated with more positive emotions such as athleticism. The present, preliminary cross-sectional results can provide ground for further studies that aim to compare sports in terms of affective benefits with more in-depth experimental methods. Furthermore, it can provide also guidance regarding expected emotional benefits of doing various sports.

Informed consent was obtained from all participants included in the study.

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**Table 1.** Post-Hoc differences concerning negative affects along each sport

| | Athletics | Badminton | Basketball | Boxing | Dance | Gymnastics | Handball | Horse Riding | Martial Arts | Soccer | Swimming | Volleyball |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Badminton** | 0.002* | - | - | - | - | - | - | - | - | - | - | - |
| **Basketball** | 0.113 | 0.049* | - | - | - | - | - | - | - | - | - | - |
| **Boxing** | <0.001* | 0.228 | <0.001* | - | - | - | - | - | - | - | - | - |
| **Dance** | 0.005* | 0.318 | 0.151 | 0.010* | - | - | - | - | - | - | - | - |
| **Gymnastics** | 0.384 | 0.016* | 0.518 | <0.001* | 0.037* | - | - | - | - | - | - | - |
| **Handball** | 0.003* | 0.599 | 0.080 | 0.049* | 0.599 | 0.022* | - | - | - | - | - | - |
| **Horse riding** | 0.010* | 0.386 | 0.211 | 0.021* | 0.970 | 0.063 | 0.069 | - | - | - | - | - |
| **Martials Arts** | 0.262 | 0.018* | 0.599 | <0.001* | 0.395 | 0.870 | 0.023* | 0.073 | - | - | - | - |
| **Soccer** | 0.105 | 0.018* | 0.823 | <0.001* | 0.026* | 0.568 | 0.021* | 0.076 | 0.682 | - | - | - |
| **Swimming** | 0.122 | 0.054 | 0.992 | <0.001* | 0.180 | 0.518 | 0.096 | 0.221 | 0.599 | 0.823 | - | - |
| **Volleyball** | 0.992 | 0.010* | 0.216 | <0.001* | 0.025* | 0.493 | 0.016* | 0.034* | 0.385 | 0.221 | 0.220 | - |
| **Non-Sport club** | <0.001* | 0.926 | 0.002* | 0.078 | 0.100 | <0.001* | 0.518 | 0.223 | <0.001* | <0.001* | 0.004* | 0.001* |

*Notes:* The table depicts the $p$ values. We considered significant differences between sports in the case of $p<0.05$. *Significantly different

**Table 2.** Post-Hoc differences concerning positive affect according to each sport

| | Athletics | Badminton | Basketball | Boxing | Dance | Gymnastics | Handball | Horse Riding | Martial Arts | Soccer | Swimming | Volleyball |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Badminton** | <0.001* | - | - | - | - | - | - | - | - | - | - | - |
| **Basketball** | 0.049 | 0.040* | - | - | - | - | - | - | - | - | - | - |
| **Boxing** | 0.006* | 0.474 | 0.238 | - | - | - | - | - | - | - | - | - |
| **Dance** | <0.001* | 0.704 | 0.013* | 0.593 | - | - | - | - | - | - | - | - |
| **Gymnastic** | 0.126 | 0.0247 | 0.710 | 0.154 | 0.008* | - | - | - | - | - | - | - |
| **Handball** | 0.010* | 0.192 | 0.427 | 0.606 | 0.173 | 0.286 | - | - | - | - | - | - |
| **Horse riding** | <0.001* | 0.403 | <0.001* | 0.087 | 0.100 | <0.001* | 0.007* | - | - | - | - | - |
| **Martial Arts** | 0.039* | 0.049* | 0.900 | 0.266 | 0.018* | 0.655 | 0.486 | <0.001* | - | - | - | - |
| **Soccer** | 0.286 | <0.001* | 0.126 | 0.012* | <0.001* | 0.341 | 0.016* | <0.001* | 0.093 | - | - | - |
| **Swimming** | 0.002* | 0.313 | 0.219 | 0.837 | 0.3412 | 0.137 | 0.690 | 0.018* | 0.259 | 0.002* | - | - |
| **Volleyball** | 0.403 | 0.033* | 0.517 | 0.141 | 0.025* | 0.700 | 0.251 | 0.001* | 0.474 | 0.837 | 0.141 | - |
| **Non-Sport club** | <0.001* | 0.061 | <0.001* | 0.002* | <0.001* | <0.001* | <0.001* | 0.259 | <0.001* | <0.001* | <0.001* | <0.001* |

*Notes:* The table depicts the $p$ values. We considered significant differences between sports in the case of $p < 0.05$. *Significantly different.

**Figure 1.** (Caption) Negative and positive affects along the most practice   French sports club memberships and those who do not practice sports among adolescents aged between 10 and 18 years.

*Note.* The left panel (A) depicts negative affect-related results. The right panel (B) depicts the main effect of the sports club membership on positive affects. Only those sports are depicted that were mentioned by at least 240 adolescents. The line within the boxes indicates the median value, while the triangle on the top of the boxes indicates group means, the dots indicate extreme values (outliers).

# The Use of Eye Tracking in Evaluating the Success of Golfers in Putting

Bc. Klára Gajdošíková

***Abstract***—The aim of the study *The use of eye tracking in evaluating the success of golfers in putting* was to examine the quiet eye method and its components using the mobile eye tracking device. Quiet eye training was proven to be beneficial for different sports, including golf. The main idea of this method is prolonging your fixations on a specific place in order to improve your performance. Shot examined in this study is called *putt*. Its importance is based on its role on a golf course because many times it is the last putt that decides whether you win or loose. Quiet eye training helps players be more focused under pressure, control their attention and overall improve their putting success.

Six highly skilled golfers with handicap range from - 4 to + 4, aged 23 to 26 participated in a pilot study with the usage of an eye tracking device. The study took place in an indoor training area at golf club Hostivař. Crosstabs showed significant differences between individuals laterality and their gaze into AOI - *areas of interest* (middle part of the ball, top of the ball, bottom of the ball, back side of the ball). Statistically significant differences were also discovered between the mean fixation duration of participants with AOI on the middle part of the ball and all other AOIs.

Results of this study helped us understand the examined phenomena and showed us the next aim in future quiet eye research. Future research should focus on examining quiet eye on the golf course. Applying quiet eye and therefore changing the way we concentrate might be beneficial for coaches and players themselves.

***Keywords***—Eye tracking, golf, laterality, quiet eye

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# High Arousal and Athletic Performance

Turki Mohammed Al Mohaid

***Abstract—*** High arousal may lead to inhibited athletic performance, or high positive arousal may enhance performance is controversial. To evaluate and review this issue, 31 athletes (all male) were induced into high pre-determined goal arousal and high arousal without pre-determined goal motivational states and tested on a standard grip strength task. Paced breathing was used to change psychological and physiological arousal. It was noted that significant increases in grip strength performance occurred when arousal was high and experienced as delighted, happy, and pleasant excitement in those with no pre-determined goal motivational states. Blood pressure, Heart rate, and other indicators of physiological activity were not found to mediate between psychological arousal and performance. In a situation where athletic performance necessitates maximal motorstrength over a short period, performance benefits of high arousal may be enhanced by designing a specific motivational state.

***Keywords—*** high arousal, athletic, performance, physiological.

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