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Performance of Produced Water

Potential of Artificial Intelligence

Highlights

Manufacturing of Conductive Yarns

Stocastic Modelling of Scaling Index

Discovering Thoughts, Inventing Future

VOLUME 23 ISSUE 3 VERSION 1.0

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Manufacturing of Conductive Yarns and Fabrics to Produce Piezoresistive Pressure Sensors: A Review

By Lefayet Sultan Lipol, Tasnia Akter Tonu, Sraboni Ahmed, Most. Jannatul Ferdous & Nusrat Jahan
Northern University Bangladesh

Abstract- Piezoresistive pressure sensors are manufactured frequently by the researcher around the world currently. The most of the sensors are passive in nature. The yarns may be intrinsically conductive, i.e. stainless steel yarn or it may be made conductive by coating, i.e. graphene oxide coated polyester yarn. The stainless steel yarn is embroidered in the fabric. When installed inside a garment, the sensors can track both muscle activity and vital signs in people. The polyester fabric that dip-coated with graphene oxide (GO) has a wide detection range and good sensitivity, making it suitable for use as a pressure sensor in plantar measurement and gait-analysis applications.

Keywords: *textronics, conductivity, piezoresistive, actuator, sensor.*

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Manufacturing of Conductive Yarns and Fabrics to Produce Piezoresistive Pressure Sensors: A Review

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Abstract- **Piezoresistive pressure sensors are manufactured frequently by the researcher around the world currently. The most of the sensors are passive in nature. The yarns may be intrinsically conductive, i.e. stainless steel yarn or it may be made conductive by coating, i.e. graphene oxide coated polyester yarn. The stainless steel yarn is embroidered in the fabric. When installed inside a garment, the sensors can track both muscle activity and vital signs in people. The polyester fabric that dip-coated with graphene oxide (GO) has a wide detection range and good sensitivity, making it suitable for use as a pressure sensor in plantar measurement and gait-analysis applications.**

Keywords: textronics, conductivity, piezoresistive, actuator, sensor.

I. Introduction

A textile fiber is a long, incredibly thin piece of material.

- Synthetic fibers typically have a very low conductivity of less than 10^{-07} S/cm, while the conductivity of conductive fibers ranges from 10^{-6} to 10^{6} S/cm.
- The fiber must also meet standards for use in textile applications and for the various stages of textile manufacturing.
- The conductive fiber must be washable if the final product must be washable.
- The conductive fiber must not affect the environment, which is another crucial factor.
- Conductive fibers have a variety of known applications, including antistatic, ESD shielding, heating, and power transfer. Other application areas for conductive fibers might be as sensors or to propagate signals.
- The test was performed in the ESD lab where the relative humidity was (12±3) % and the temperature was (23±2)°C. (4)

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Textronics is not just "textiles plus electronics" but textile itself as a sensor that can sense and react to the world around them; this qualifies it to be called "textile-based."

a) Objectives

- To produce conductive yarns and fabrics with conductive coating.
- To check the properties of the conductive yarns and fabrics.
- To produce the piezoresistive pressure sensors from the conductive fabric.

b) Research Questions

- Is it possible to use cotton yarn as core material instead of polyester?
- Is it possible to wash the conductive fabric?
- Is it possible to get consistent piezoresistive effect with the graphene oxide coated fabric?
- Is it possible to achieve sufficient elasticity of conductive yarns to produce fabric in loom?
- How do we protect the conductive materials of conductive textiles during production of fabric in knitting machine and loom (yarns friction with parts)?
- How do we measure the pulse rate and elbow movement with pressure sensors?
- How do we manufacture the different Piezoresistive pressure sensors?
- Is it possible to make the pressure sensors cost-effective?

c) Types of Wearable Textronics

When integrated into textiles, electronics can keep track of our body and communicate with other devices to make everyday tasks more manageable. The types of wearable Textronics that are mentioned below:

- Textile-based sensors: pressure sensors, strain sensors, temperature sensors and electrochemical sensors.
- Textile based electrodes
- Heating textiles
- Energy harvesting textiles
- Textile-based energy storage
- Textile based communication (2)

d) Textile-Based Sensors

In the modern digital age, wearable technology is a hot trend, and sensors are its essential components. The sensors are meant to perceive changes in the environment, whether they be physical, chemical, or in any other way. Actuators, in contrast, provide data to the wearer or an external device regarding the change that the sensor has noticed. It is difficult to embed electronic sensors and actuators in textiles because they are constructed of solid inorganic materials or metals that are either solid or enclosed in solid housings. They are also uncomfortable to wear and lack flexibility, wash ability, fatigue resistance, and wear ability. Due to these restrictions and other related technical problems, it is now necessary to produce new materials and engineering methods in order to combine electronics and textiles.

Active and passive sensors come in two varieties. While the latter need an external power source to operate, active sensors can transform input energy into quantifiable output signals without it. The majority of textile-based sensors are non-active. Electromechanical and electrochemical wearable textile sensors are two categories that are the subject of intensive research. While chemical changes trigger a response in chemical sensors, mechanical forces cause electromechanical sensors to produce an electric signal. For instance, strain sensors and pressure sensors are used to monitor a wearer's breathing rate, heart rate, muscular activity, and gestures that are brought on by a mechanical force or stretching of the body. In contrast, sweat changes can be detected using a pH sensor, and changes in glucose or lactate can be detected using a bio molecular sensor. Additionally, scientists are developing intelligent clothing that has textile-based sensors built in to measure body temperature, vital signs, and other chemical changes. (1)

e) Applications in Sports

One of the first industries to start utilizing the advancing Textronics technology is the sportswear sector. The way athletes are coached and physically monitored during competition has the potential to alter dramatically thanks to smart gear. Major sporting brands have released a number of e-textile products on the market, and demand for most of them is rising quickly. A smart sock having built-in textile-based sensors that can track an athlete's speed, distance traveled, and number of steps taken. By monitoring the foot landing patterns, the Sensoria smart sock can also assist in identifying running techniques that are prone to damage. The information is wirelessly transmitted to a mobile application running on a smartphone through a removable Bluetooth component. One of the key methods for a runner to monitor their performance is gait analysis through pressure profiling. Sports bras and smart shirts can also be produced.

II. Materials and Methods

a) Materials and Machines Required

- Cotton, Polyester and Stainless steel yarn.
- Embroidery machine
- Plain stitch machine
- For weaving/Knitting: Rib Circular Knitting Machine, Single Jersey Circular Knitting Machine, Rapier Loom, Socks machine, suitable environment
- Chemicals: Graphene oxide, sulphonate dopant, oxidizing agent.
- Testing instruments: Scanning Electron Microscope; The Voltmeter, The Multi meter, Crocodile clips, The fixer, Vapor Phase Polymerization chamber, Incubator or Dryer, Pico ammeter, FTIR, Tensile Testing m/c, Extensometers, Co-efficient of Friction Tester, Martindale abrasion tester, Washing machine.

b) Conducting Polymer Coated Textiles

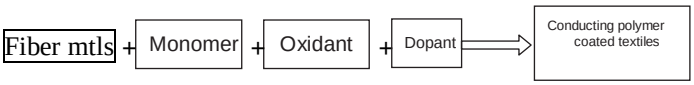

Figure 1: General Procedure of Coating a Conducting Polymer on Textiles (2)

c) Testing of Conductive Coatings

Conductivity, Coating thickness, Coating fastness evaluation, electrical conductivity and antistatic performance, frictional properties, durability, tensile properties.

III. Results and Discussion

Resistive, capacitive, and piezoelectric components make up textile-based pressure sensors. When a compressive mechanical force is applied, they generate an electrical signal. These sensors are often woven with conductive yarns or fabrics coated with conductive polymers. In response to the mechanical stress, they alter their resistance, capacitance, or produce an electric charge. These sensors are essential for getting the highest functional and sensing performance in a wearable, depending on their use. Over the past ten years, there has been a significant advancement in the development of textile-based pressure sensors because to their many benefits,

including their high flexibility, low cost, and simplicity of integration into wearable's.

When squeezed, piezoresistive sensors change their shape, which changes the contact area between the conducting material and affects resistance. Due to their straightforward construction and straightforward production method, piezoresistive-based pressure sensors are explored in greater detail than other wearable pressure sensors. These sensors also use less electricity and have numerous uses in both sports and medicine.

In recent years, research has been done to create textile-based piezoresistive sensors using several types of conductive materials (yarns/fabrics). Generally speaking, they fall into two categories: naturally conductive and carefully processed conductive yarns and textiles. Stainless steel (SS), nickel, copper, aluminum, and other metals are frequently used to make intrinsically conductive yarns, which are based on metal yarns or filaments. Similar to this, fabrics made of metal threads are referred to as inherently conductive fabrics. Examples include knitted fabrics made of stainless steel or copper mesh. Conductivity is added to specially prepared conductive yarns or fabrics by additional processing processes like printing, coating, etc. Among the most common are conductive coatings made of carbon. Figure 2 a, b shows an intrinsic conductive yarn and fabric, whereas Figure 2 c, d shows an example of a specially treated conductive yarn and fabric.

Piezoresistive sensors that are stitched-based have been created utilizing SS yarns and a sewing machine. When installed inside a garment, the sensors can track both muscle activity and vital signs in people. The article described a novel fabrication method to build force sensing resistor (FSR) concept-based wearable textile sensors. Similar to this, metallic yarns were coated with a carbon-based conductive polymer solution to improve the pressure sensitivity in a yarn-based force sensor created by Parzer et al. Additionally, a resistive pressure sensor made of graphene was reported and utilized to track elbow movements and human heart rate. The polyester fabric that Lou et al. dip-coated with graphene oxide (GO) has a wide detection range and good sensitivity, making it suitable for use as a pressure sensor in plantar measurement and gait-analysis applications. Piezoresistive sensors are a strong choice for the next generation of wearable sensing due to their simple construction, great responsiveness, and repeatability. Examples of textile-based pressure sensors are shown in Figure 3.

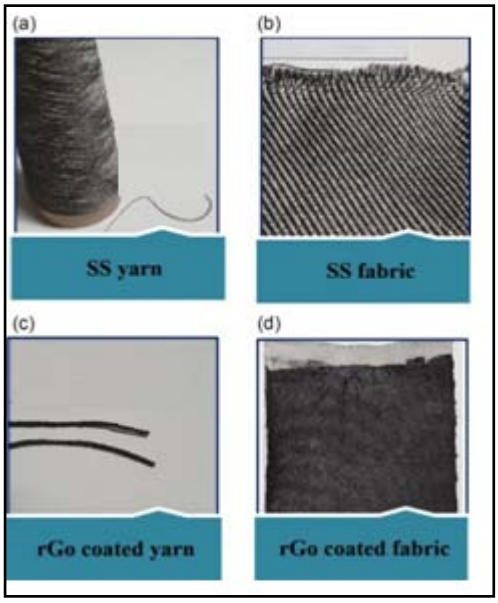

Figure 2: a) SS yarn. b) SS fabric. c) Reduced Graphene Oxide (rGO)- Coated yarn. d) rGO-Coated Fabric.[1]

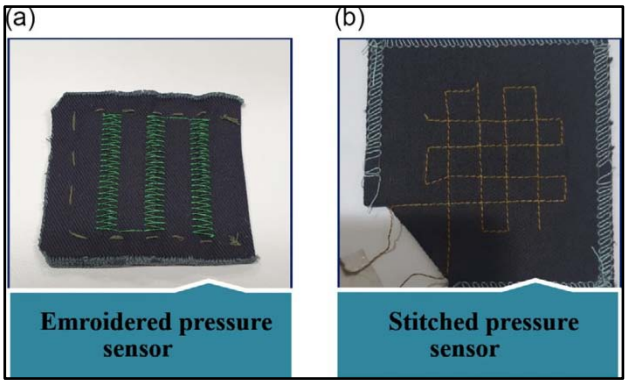

Figure 3: a) Conductive thread-based Embroidered Pressure Sensor. b) Stitched Pressure Sensor. [1]

IV. Conclusion

The conductive yarns and fabrics are essential for the production of piezoresistive pressure sensors. The fiber material is coated with monomer, oxidant and Dopant. Moreover, the fiber may be intrinsically conductive like SS yarn. The conducting threads are attached with the fabric by stitching or embroidered machine. When the sensors are attached in the garments, it can detect the plantar measurement and gait analysis etc. The researchers are working continuously to find different products from the piezoresistive pressure sensors.

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Unleashing the Potential of Artificial Intelligence in Architecture and Development of the Built Environment: From Misconceptions to Productive Prospects

By Michal Sourek
Czech Technical University in Prague

Abstract- Artificial intelligence invades our lives and professions at an ever-increasing pace and intensity. Architecture, the built environment, and real estate have been joining the trend only timidly and belatedly. The record of some of the most recent "famous achievements" in the field set straight, the paper challenges the state-of-the-art concerning these fields, debunks the idea of the (truly) creative potential of the technology, and puts forward a sketch roadmap to a realistic - and significant - deployment of artificial intelligence in architecture and the built environment. The attention turns to open-source patterns-platforms, generative patterns processing, generative pre-design, parametric evaluation, and optimization. Leveraging the objectivity of assessments and streamlining workflows, artificial intelligence promises to unleash true architectural creativity and leverage the productivity and efficiency of the design- and planning processes.

Keywords: *artificial intelligence, machine learning, generative pattern, open-source platform of patterns, generative pre-design, parametric review, parametric optimization.*

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Keywords: artificial intelligence, machine learning, generative pattern, open-source platform of patterns, generative pre-design, parametric review, parametric optimization.

I. Introduction

Artificial intelligence, as algorithmic computer programs are called that can generate data from heterogeneous, most often textual and image templates or patterns, evaluate these large data sets according to complex criterion structures, generate downstream new algorithms, and use them to generate outputs of a nature identical or subsequent to the initial templates and patterns, is considered "the next level" in the field of visual design - and architecture hopefully, too. Only belated, however, architecture, the development of the built environment, and real estate have been joining the trend of artificial intelligence that has been entering our lives and professions since the 1980s.

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a) Reimagining Architecture and Development of the Built Environment

Not by chance, the wavering approach to the new technology tunes with these disciplines´ failures to cope with societal and economic development; in architecture, it has been a reality for at least 70 years. At the same time, the influence and impact of the disciplines´ general performance on the economy, social affairs and issues, and sustainability are immense. The society´s dissatisfaction with the state and development of the built environment has been increasing through recent decades, but a comprehension of the causes is lacking. The remedy efforts are marginal and shattered, failing to address the appropriate goals and adopt efficient way and tools.

The need for the field´s paradigm change renders: to support the change, new, promissing technologies appear, such as virtual reality and artificial intelligence (AI), that could improve architectural and planning practices. Virtual twins offer unprecedented abilities to create, understand, and communicate architecture and the built environment, while AI provides machine-learning capabilities for design, planning, and parametres´ review and assessment. The nature of the technologies and their potential have to be understood correctly first - which, so far, is only rarely the case in the professions moving around built environment and real estate with the architectural craft at their heart.

b) Achievements, Misonceptions, and Prospects of AI in Architecture

The virtual twins' technology, its benefits and prospects are reviewed in [1]; this paper sets it aside and concentrates on AI. First, the paper challenges the existing approach to AI´s deployment within architectural design, its theoretical starting points, and the perspectives put forward so far. To do so, the framework of a state-of-the-art of the field is introduced; the methods used and expectations declared are assessed within the framework. Section (III)

provides a general summary of the achieved results, which will be extensively discussed in the subsequent section (IV). The overview serves as a foundation for identifying the misunderstandings and limitations of recent attempts and expectations regarding the use of AI in architecture, the built environment, and real estate - for debunking some of the "fantastic achievements of AI promising to make man redundant" contemporarily discussed in the profession and beyond. In contrast, other, so far not considered perspectives of AI in architecture and development of the built environment render: in parametric development and assessment of diverse outputs of creative architectural and urban design concepts, and in approaching to sustainable development (or, better, to the comprehensive resilience) tasks. Finally, Discussion (IV) sketches how AI could contribute to an upheaval of the architectural profession by overcoming its recent and contemporary technological lacking behind; the true, authentic architectural creativity will not back off by the technology – the opposite, it will be unleashed. Conclusions (V) outline the principles of aiming and particular goals of further development of machine learning for the good of architecture, the built environment, and sustainable development.

II. State-of-the-Art, Methods, and Expectations

Since around 2010, global star-architectural studios alongside young enthusiasts combining information technology and architecture try to embrace AI´s potential contribution to architectural design or, better to say, disclose where from it might stem and what it might consist of. In 2020, *DeepHimmelb(l)au - a video of a journey through an imaginary landscape of Coop Himmelb(l)au-like building forms* - has come into existence. The result of the elaboration of datasets comprising *reference images of geomorphic formations* on the one hand and *actual Coop Himmelb(l)au projects* on the other by CycleGAN and other forms of GAN technologies provided "*machine hallucinations*" [2,3,4] - represented prevailingly in two dimensions, substantially lacking both spatial comprehensivity and the for architecture inherent interconnectedness of the experiential (poetic, in other words) and material attributes that will be discussed further in (IV).

a) How a Machine Can Learn

Though generally (and in this paper, too) labeled as AI, the term machine learning adheres better to the use of the technology in architecture: learning or training is the keyword. The base for the learning is a set of data possessing the same characteristics as the data to be generated: a truly large file as will be shown in (IV), and a comprehensive one; what is not in it, the AI cannot learn. Variations of machine learning deserve reminder: supervised learning, unsupervised learning, reinforcement learning, and various fusions.

In supervised *learning, the system is given a series of categorized or labeled examples and told to make predicions about new examples it hasn´t seen yet, or for which the ground truth is not yet known* [5]. Supervised learning uses labeled datasets, whereas unsupervised learning uses unlabeled datasets. “Labeled”, means the data already tagged with the requested answer. In supervised learning, the learning algorithm measures its accuracy through the loss function, adjusting until the error has been sufficiently minimized. Two types of supervised learning distinct - classification and regression. Classification uses an algorithm to accurately assign test data into specific categories. It recognizes specific entities within the dataset and attempts to draw some conclusions on how the entities should be labeled or defined. Common classification algorithms are support vector machines, linear classifiers, decision trees, k-nearest neighbor, random forest, and others. Regression applies to understand the relationship between dependent and independent variables - commonly to make projections. Linear regression, logistic regression, and polynomial regression are popular regression algorithms. [6]

Unsupervised learning analyzes and clusters unlabeled datasets. These algorithms discover hidden patterns or data groupings without the need for human intervention - without the need for labeling the datasets. *In* unsupervised *learning, a machine is simply given a heap of data and told to make sense of it, to find patterns, regularities, usefull ways of condensing or representing or visualizing it.* [5,7]

Reinforcement learning concerns how intelligent agents ought to take action in an environment to maximize the notion of cumulative reward. Reinforcement learning differs from supervised learning in not needing labeled input/output pairs to be presented, and in not needing sub-optimal actions to be explicitly corrected. Instead, it focuses on finding a balance between exploration (of uncharted territory) and exploitation (of current knowledge). In other words, *placed into an environment with rewards and punishments, [the system is] told to figure out the best way to minimize the punishments and maximize the rewards* [5,8]. As the comprehension upgrades of learning processes and - especially - of consequences of their details for the outputs, the reward signals to fine-tune the models tend to be human preferences based (referred to as *reinforcement learning from human feedback* [9]) instead of simple automatic metrics. Indicated further in this section, the safety and alignment problems are the starting point for the deployment of these approaches that are much more time- and cost-consuming. Such is, for example, the case of InstructGPT - one of the most advanced language models today.

b) Artificial Neural Networks

Approaching the mentioned GAN (generative adversarial network) technologies (approaching only superficially in this paper´s framework), artificial neural networks can be described as a type of machine learning model that can be used for various tasks, including deep learning, Bayesian learning, and more. An artificial neural network is a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal to other neurons. An artificial neuron that receives a signal then processes it and can signal neurons connected to it. [10,11]

Designed by Ian Goodfellow and his colleagues in 2014, GAN is a class of machine learning frameworks. Representing today´s state-of-the-art, GAN is a milestone of R&D launched by neurophysiologist and cybernetician of the University of Illinois at Chicago Warren McCulloch and self-taught logician and cognitive psychologist Walter Pitts. In 1943, the two published the foundations-laying article A Logical Calculus of the Ideas Immitent in Nervous Activity [12]. Building on Allan Turing´s work On Computable Numbers, McCulloch´s and Pitt´s paper set a path to describe cognitive functions in abstract terms showing that simple elements connected in a network can have a huge computational capacity.

The first implementation of McCulloch´s and Pitt´s theoretical starting points was a machine built in 1958 at the Cornell Aeronautical Laboratory by Frank Rosenblatt. *The perceptron was intended to be a machine, rather than a program, and while its first implementation was in software for the IBM 704, it was subsequently implemented in custom-built hardware as the "Mark 1 perceptron". This machine was designed for image recognition: it had an array of 400 photocells, randomly connected to the "neurons". Weights were encoded in potentiometers, and weight updates during learning were performed by electric motors.* [13] By the end of the 1950s, *IBM´s Arthur Samuel had built a program to play checkers that, in a crude and early way, adjusted its parameters based on won and lost games. Soon after Samuel was losing matches to his own creation*: behold, reinforced machine learning. [14]

c) Infering by Computing

Building upon "the founding fathers´" achievements, the idea of GAN copes with evolutionary biology principle of an arms race between two species. Two neural networks contest with each other in the form of a zero-sum game, where one agent's gain is another agent's loss. The core principle of a GAN is an "indirect" training through the discriminator – competitive network agent that can tell how "realistic" the input seems, which itself is also being updated dynamically. *This means that the generator gets no training to minimize the distance to a specific image, but rather to* fool *the discriminator. This enables the model to learn in an unsupervised manner; however, GANs have also proved useful for semi-supervised learning, fully supervised learning, and reinforcement learning*.[15]

An artificial neural network works by computing. In essence, two principles of computing apply in artificial neural networks: feedforward computing and backpropagation. The goal is always to *train* the models generated to cope with the criteria inserted typically by vast collections of sample datasets. Feedforward computing refers to a type of workflow without feedback connections that would form closed loops; the latter term marks a way of computing the partial derivatives during training. When training a model in the feedforward manner, the input "flows" forward through the network layers from the input to the output. By contrast, while using backpropagation, the model parameters update in the opposite direction: from the (one closer to) output layer to the (one closer to) input one. However, the backpropagation algorithm shall not be confused with training algorithms that provide the model dataset updates; backpropagation is a strategy to compute the gradient in a neural network. Backpropagation is a general technique; in terms of neural networks, it is not restricted to feedforward networks, it works for recurrent neural networks as well. [16]

"Fed" by inputs, the networks deliver outputs "at the end" that try to mimic the deliverables of human work. The principle is that artificial networks deliver relentlessly, very quickly, and in huge quantities - as opposed and by contrast to humans. The vision is that amidst these quantities in no time at all emerge outputs that not only mimic but also attain, if not surpass the quality of human performance. The vision still leaves something to a human - the choice of the most suitable output provided and its fine-tuning, but who knows - one day... Objectively, an evaluation of solutions due to a given set of criteria is a task suitable for computer, too - a task easier in principle than a creation.

d) Networks´and Techniques´ Evolution

GANs, a recent revolution in machine learning provides results today that achieve appreciation, as Leach [17] puts. First introduced in 1987, the pioneers were convolutional neural networks (CNNs), also known as shift invariant or space invariant neural networks, most commonly applied to analyze visual imagery. [18] ImageNet, a groundbreaking project from the 2010s builds on this technology. [19] Graph neural networks (GNNs) are another field of recent research aiming at the processing of graph data. And various applications of GANs are still emerging: FrankenGAN for urban context massing, detailing, and texturing, Pix2PixHD by Nvidia for high-resolution photorealistic image-to-image translation, GAN Loci, or GauGAN. [20]

Variational auto-encoders (VAEs) develop another technique. [21] Unlike GAN, instead of the *generator – discriminator* pair, Variational Autoencoder combines two distinct approaches - *encoding* and *decoding*. Encoder abstracts data by compressing while decoder brings the data back to its initial format. Through the decompression, or "reparametrization", the decoder generates variations of the modeled phenomenon. [22] The ability to emulate a phenomenon by generating multiple versions of it is a starting point of VAE´s generative potential to provide large quantities of "outputs" (as AI enthusiasts heralding the twilight of design call it) - typically in furniture design, fashion, photography, architecture, and urban design. [23]

Oposed to the above outlined *discriminative* and/or *decoding* techniques that *identify* objects and *infer* what is “real” and what is “fake”, generative AI systems *create* objects such as pictures, audio, writing samples, and anything that can be built by computer-controlled systems like 3D printers. [24] Generative AI allows machines to create new works based on what they have learned from others. With such a straightforward deployment, a question arises of how much the (so far existing) generative AI systems are truly AI-driven in terms of computational networks and processes; however, in the practical framework of this paper, the resolution is not of substantial meaning. As a principle, generative and discriminative or decoding systems most often operate paired in GAN models setting the benchmark of today´s AI industry. Typically, a system labeled as generative AI is self-learning, it uses unsupervised learning (but can use other types of machine learning, too), and deploys anomaly detection and problem-solving - it can come up with innovative solutions or approaches based on its experience with similar problems in the past. [25]

e) General Context to Compare

There are ecosystems of natural language processing, image processing, voice processing, and code or software processing and development, further robotics, and expert systems or business intelligence [26,27], altogether represented by Dall-E (Dall-E2 most newly), ImageGPT, GPT-3.5 and the latest GPT-4, InstructGPT and ChatGPT and other tools by OpenAI, also Midjourney, Stable Diffusion, Gong.io, Tellius, OPENNN, Theano, and many other tools by multiple producers. These ecosystems exist, evolve, and (some of them) work (though sometimes obscured, even covered up) already over decades and render mature.

After the first, largely experimental AI models - the percepton and Samuel's checkers player - slowly-slowly, practical or even commercial AI applications have been arriving: ELIZA in 1966, developed by Joseph Weizenbaum for MIT, was the first chatbot in history that replicated a therapist giving general answers to users' questions, simulating a real conversation; PARRY, developed in 1972 by Kenneth Colby at Stanford University to simulate a schizophrenic patient and replicate therapeutic conversations, terminated in 1978; RACTER developed by William Chamberlain and Thomas Etter - a chatbot capable of generating poems and science fiction stories, published by Mindscape in 1984 and active until 1991; A.L.I.C.E. - Artificial Linguistic Internet Computer Entity eveloped in 1995 by Richard Wallace - a chatbot that could mimic a conversation with a human, active until 2018; SmarterChild, a virtual assistant on AIM, MSN Messenger and Yahoo! Messenger developed by ActiveBuddy in 2001 operating until 2008 when its activities were terminated; Doretta, released in 2007 helped to search the Internet for what users of Windows Live Messenger do; Siri, one of the first successful virtual assistants, developed in 2010 by Apple for iOS devices is still active and evolving; Alexa developed in 2014 by Amazon is also a virtual assistant that can be used through the Echo device, still active and evolving just like Google Assistant or BERT, both developed by Google in 2016 and 2018 respectively; BERT is an artificial intelligence model that can understand the context of the conversation and provide more accurate and personalized responses, used as the basis of many modern virtual assistants. [28]

The "good old" AI applications that have been reading postal codes for USPS since the very beginning of the 1990s, have been deciding on custody and bail in many US states and liquidating insurance claims, and have been a tool of economic efficiency of the US healthcare through last two or three decades being indicated only superficially,[29] numerous “more fresh” straightforward concepts of generative AI beyond deserve more attention. An excellent example is the creation of new medical images, such as those *used in retinopathy diagnosis. Using it, physicians can create new patient records, which can then be incorporated into the system to improve accuracy. To train these applications, they use large amounts of real-world patient data to generate new images and data sets that humans could have never developed.* Analyzing large amounts of data efficiently and quickly improves understanding of diseases significantly. *Deep Composer is AI intelligence that can create an entire song from a short melody. It is also designed to act as a personal assistant to a human to compose some simple segments first, the final composition to be assembled by AI. A wide range of common music genres is pre-trained in the system.* Some of IBM's generative models are used in drug design *to propose new molecules that could work as drugs by training them to generate structures in relation to expected functions*. Game developers - Nintendo, Rockstar Games, Valve, Activision, Electronic Arts, and Ubisoft among others - are adept at creating artificial worlds *and telling stories based on them by their very nature. Expertise of game developers in creating and*

deploying diverse algorithms that generate the game narratives and scenes often goes back decades before AI was defined as an umbrella term. Generative AI shapes ever-more *the fashion industry and the art world, where brands and artists - or AI users? - can create original designs that look like human artists created them.* Such is the case of Lalaland.ai, a Dutch startup that provides a *self-service platform where users can create their own hyper-realistic AI-driven fashion avatars in just minutes. Users may customize the virtual models' size, body type, shape, and identity—even down to whether they are happy or sad. In the financial sector, banks are using generative AI to automate tasks such as checking account openings and loan approvals. And more than one startup has already begun applying generative AI to create virtual assistants who can respond appropriately to human requests with natural language processing and dialogue management capabilities.* [30]

Not only professionals but the general public, too, has started to employ AI: from initial misconception to more mature approaches and understanding. To advanced users, chatbots serve as a sixth sense or a counterpart able to respond to questions. The quality of the responses is disputable as a whole, however better and worse questions exist that generate better or worse answers. Labeled as *prompting*, the art of questioning that stands behind any authorship creation since time immemorial experiences a revival and an upgrade to the next level.

It's a real influx of ever-new AI tools what the present experiences. During the fourth week of March 2023 alone, 200 new applications were released. [31] The week before, OpenAI dropped yet another state-of-the-art large language model, GPT-4, equipped with multimodal capabilities and superior performance on benchmarks designed for humans. Stanford released Alpaca 7B, a relatively small open-source model that matches the performance of GPT-3.5. Concurrently, Google introduced Bard - the "*creative and helpful collaborator, here to supercharge your imagination, boost your productivity, and bring your ideas to life*" [32], Chinese search engine behemoth Baidu released (just before April 14, 2023) Ernie Bot [33], Alibaba Group introduced (April 11) chatbot Tongyi Qianwen, Sense Time SenseChat [34], and Amazon its new AI application Bedrock, which makes available to developers generative tools for creating texts and images. (Now, Amazon offers four AI applications, the native Titan included, and employs the most people in AI development – more than both Google and Microsoft.) [35]

Transversally to the closed corporate releases on large language models, there have also been clever ideas and breakthroughs in the field of natural language processing. A new training strategy of meet-in-the-middle (MIM) [36] has been shown to improve not only the performance but also the interpretability and thus security (to be explained later) of large language models. Significant progress arrived in computer vision, in both diffusion models and neural radiance fields (NeRF) [37] - a type of machine learning algorithm used for 3D modeling and rendering based on deep neural networks capable of generating high-quality, photorealistic images of complex scenes from multiple viewpoints. The new Mesh Diffusion [38] - another fresh arrival - allows direct generating 3D meshes without any post-processing, and also new Fate Zero [39] can edit the style of the videos using text while keeping the pre-trained model weights intact. Last but not least, the same week a beautiful marriage of NeRF with CLIP (contrastive language-image pre-training) [40,41] arrived: LERF (radiance embedded radiance ields) [42]. With it, natural language queries in a 3D fashion can apply within NeRF, targeting different objects in the scene. This brief overview highlights several new types of algorithms that may represent the first steps toward productive prospects for deploying AI in architecture. These algorithms, developed (most likely) with no regard to architectural design, may break out of the misconceptions that have so far dominated these efforts, as section (III) of this paper will show, while section (IV) discusses the emerging positive prospects of AI's contribution to the architectural craft.

f) The Black Box Problem, Security Issue, and a Threat to Humanity

However, *with all these nice results, it's not clear what these models are learning*, as Mathew Zeiler puts it. [43]As AI becomes more advanced and ubiquitous, concerns around the security of AI systems have become increasingly prevalent. AI systems are vulnerable to various types of attacks and data "poisoning", which involve intentionally manipulating the input data to cause it to produce incorrect or malicious output, injecting malicious or misleading data into the training data set, which can result in biased or inaccurate models, or inserting a hidden trigger or behavior into an AI system that can be triggered by a specific input or action, allowing an attacker to gain unauthorized access or control over the system.

Another significant challenge in the development and use of AI systems is the black box problem. AI systems often involve complex algorithms and models that are more or less impossible for humans to interpret or understand. This can create a lack of transparency and accountability in AI decision-making, as it can be unclear how the system arrived at a particular output or decision, or even obviously incorrect or misleading outputs are delivered occasionally submitting unintended consequences or biases, also in ethical and legal concerns. Such a threat cannot be overestimated as it is inherently embedded in the nature of the learning process. The algorithm does not work -

because by definition it cannot work - with the categories "true" or "false", but deduces the degree of conformity or deviation according to patterns arrived at by own judgment, either without human supervision or under human supervision or direction, but always covertly in detail. In cases - not exceptional - when subsequent analysis reveals systematic or ocassional inaccuracy of the outputs, confusion of cause and effect in the training data, diverting attention to the background of graphic inputs (bokeh) instead of their core, or similar is usually shown as the cause.

The bokeh salience feature of AI provides a comprehensive clarification of„ famous“ *Coop Himmelb(l)au “machine hallucinations”* [2,3,4]. Not the creativity of AI appears, but a misleading perception of visual information hidden in the algorithm´s black box; not creativity, but an error and accident. Computer hallucinations by unintended bokeh salience are examples of how technology can be misused to manipulate and misinterpret visual information, either to fake art or to distort scientific research. The AI development community deserves credit for looking for and already delivering the first applications that solve this problem. Different from a point cloud or voxel-based diffusion models, the "new arrival" of March 2023 Mesh Diffusion [38] can enjoy the modern graphics pipelines optimized for operating with meshes, e.g. relighting or simulation. Other than the unconditional generation of meshes, the model is also capable of conditional generation with single-view images and shape interpolation. For efficacy, the uniformly initialized tetrahedral grid for 4D representation is used. Training is split into two stages: First, a mapper from 2D view to the tetrahedral grid is trained to construct a dataset of grids, and second, a diffusion model (denoiser) that operates on the tetrahedral representation.

And other kinds of applications began to be developed to tackle the issue of interpretability. The already mentioned new training MIM strategy represents the first approach heading to AI systems that are inherently transparent and accountable due to the increased interpretability of the model. Interpretability represents the (human) ability to understand and explain how a particular system, model, or algorithm arrives at a particular decision or output. This way, it can help to build trust in AI systems by making their decision-making processes more transparent and understandable. It can also help in identifying and addressing biases or errors in the system, and it can enable experts to diagnose and fix any issues that arise. Interpretability can be achieved through various methods, such as visualizations, explanations, or feature importance measures. Nonetheless, achieving interpretability can sometimes come at the cost of the accuracy or performance of the system. [43]

Another way to tackle the black box issue is testing with concept activation networks; TCAN is a technique used to better understand how neural networks process information and make decisions. A CAN is a type of neural network that has been trained to recognize and represent concepts, such as objects or ideas, within an image or text. CANs are designed to mimic the way the human brain processes information, by breaking down complex inputs into simpler components and recognizing patterns within them. To test with CAN, an image or text is to be fed into the network to observe the activation of the individual concept nodes. This allows seeing which concepts the network has recognized and how confident it is in its recognition. By analyzing the activation patterns of the CAN, an insight into how the network is making decisions can be gained to identify areas for improvement subsequently. The technique can be used to diagnose problems with the network's training, identify biases in its decision-making, or optimize its performance for a specific task. [44,45]

Nonetheless, fears remain. At the end of March 2023, Italy blocked ChatGPT [46] to secure the privacy of people and tycoons of global business claim pausing "giant AI experiments" - read the development of AI for six months [47] to prevent an unmanaged reaching of the singularity phase of AI development, when a spontaneous technological growth breaks out, and not only the society begins to be irreversibly changed by the effects of technology but humanity loses all control over further development of AI.

III. Results of Applying AI in Architecture

For a paper headlined architectural, the preceding section may seem too much extensive both in terms of general orientation and when it comes to scope. However, only the technological “know-how” along with an awareness of the vast achievements of the other fields allow comprehension of how sidelined (also concerning AI) architecture is and, especially, how great the opportunities for the development of the branch are. A misconception on the nature of architecture in contrast to construction and built environment that the AI applications developers have been suffering so far is one of the reasons for the sidelining. Another reason is the multiple dimensionality and diachrony of architecture that contrast with the nature of the fields of the biggest successes of AI deployment – one-dimensional language or two-dimensional image. Compared to the double challenge – a lack of understanding and an extreme comprehensiveness of the task – the recent and contemporary applications´ development efforts show even more daring – no matter how unsuccessful a class of them is. Or is it naivety?

a) AI Models and Creates Architecture – Does It?

Among multiple others, also Zaha Hadid (studio) met AI using the technology to render forms not

so free to cease resembling antic temples patterns that served as imagery datasets to feed the GAN. [48] In doctoral research under the supervision of Patrik Schumacher of ZHA in 2017, Daniel Bolojan created Parametric Semiology Study using machine learning algorithms and other tools of gaming AI implemented in Unity 3D to model the behavior of human agents in order to test the layout of a proposed space. [49]

Stanislas Chaillou as well as Nvidia company and many others provide AI applications to generate floorplans and apartment layouts. [50] ArchiGAN uses generative networks to create 2D and 3D building designs based on input parameters such as dimensions and space requirements. Another model is CityGAN, which generates drafts of city blocks and buildings. From a practical point of view and concerning the efficiency of deployment, the results of both applications are questionable - as in all other similar cases. On the principle of image-to-image translation with conditional adversarial networks (CANs), Phillip Isola Research Group [51] provides series of machine-generated facades following the "style" and character of the pattern deployed as the "input". [52,53] Introduced by the same team, Pix2Pix is shorthand for an implementation of a generic image-to-image translation using CANs [54]. Developed in 2019 by Kyle Steinfeld [55], GAN Loci is able to generate perspective images-like of urban scenes assembled with given facades-like textures, pathways, street furniture, pedestrians, cars, etc., by training to achieve the required "mood" - suburban, public park, etc. [56,57] Blending the outcomes of Isola´s team and Steinfeld´s R&D, Sketch2Pix provides an interactive application for architectural sketching augmented by automated image-to-image translation [58].

Tom Mayne of Morphosis employed AI to develop *operational strategies, so as to generate output that could never be predicted.* The studio developed *Combinatorial Design Studies: a Grasshopper definition of one formal study* elaborated by GAN technology *provided a range of further combinatorial options* [59]. Foster+Partners, another global-star architectural studio cannot stay aside; in its *Applied R+D team architects and engineers together with expert programmers combine the best of human intuition and computational rigor working with new technologies such as augmented reality, machine learning, and real-time simulation* [60].

In terms of practical use, *predictive simulations* render the etalon. ComfortGAN, for example, investigates the challenges of predicting a building´s indoor thermal comfort [61]. Also structural design is on the lookout for AI. *Using Variational Autoencoders, for instance, research development at MIT investigates how diverse structures can be generated while ensuring performance standards* [62]. However, due to the essential material liability of the structural design, the not yet-solved problems of the algorithm´s black box that do not allow to rely on the machine curb so far the deployment of AI in structural design to the theory and conceptual drafting.

On an urban scale, attempts are ongoing to contribute by generating "typical style" road- and circulation patterns and networks using - among others - the Neural Turtle Graphics. [63,64] *Over the past decade, the deployment of online platforms has provided an adequate infrastructure to the end users*,[65] also to deploy Generative AI: Spacemaker [66,67], Cove.tool [68], Giraffe [69], or Creo [70] are a few examples of this growing ecosystem, offering simplified access to AI-based predictive models [71], *generative design, augmenting reality, real-time simulation, additive manufacturing, and IoT to iterate faster, reduce costs, and improve product.*

Not only start-ups, academia, and spin-offs of global architectural star-studios go in for AI: the global CAD-tycoon Autodesk runs Machine Intelligence AI Lab – and much of Autodesk´s software, including Fusion 360, is AI-enabled and applying generative design today [72], not to mention the acquisition of Spacemaker [73]. Nonetheless, as broad as all this listing may seem, the development of AI for and in AEC (Architecture, Engineering, Construction) is still in its infancy, failing to catch up with LLMs (large language models), text-to-image processing, deployment of AI in internet search, content placement, and advertising, but also healthcare, pharmaceuticals, insurance, or justice referring to custody and bail [74].

b) Assessment of Results Achieved in Architecturel Design

The overview of the results of applying AI in architecture achieved so far renders shattered: it is neither by accident nor by a lack of caring by the author. When AI performs well concerning parametric aspects of diverse materializations of architecture (such as construction, energy efficiency, daylighting, or noise in buildings and neighborhoods) and fails to be effective and productive in conceptual architectural design, it is not only a temporary swing in the performance of particular efforts. It is a consequence of AI applications´ developers failing to grasp and follow the starting points and the workflow of creating architecture, whether on the scale of buildings or the built environment. Only by overcoming this problem, the way will open up to the efficient and prolific deployment of AI in architecture as will be discussed later and put in (V). At the moment, however, there is a long way to go.

Unlike the text-, image-, or codeprocessing examples provided, the applications aiming at architecture and built environment are far from establishing a homogenous, rich, and prosperous ecosystem. The results delivered by AI in the field of architecture and real estate development are still profoundly experimental, and failing to provide a degree

a "creativity" and "persuasiveness" that we have got used to by text- or image processing AI. Predictive simulation tools such as Spacemaker or Cove.tool show up as, or rather, pretend successfully to be exceptions, as will be discussed later.

With respect to the undoubted qualifications and ingenuity of the authors, the results of the Phillip Isola Research Group, Kyle Steinfeld, the "typical style" road- and circulation patterns and networks delivered by Neural Turtle Graphics, and others can be considered interesting outputs of research efforts in computer science, code development, or perhaps graphics, but only scarce contributions can be identified in terms of architectural workflow and solutions. Similarly, the *parametric semiology* outcomes of Daniel Bolojan or Tom Mayne´s *operational strategies* render too speculative to provide some practical analytical starting point. *DeepHimmelb(l)au* as well as alike results of ZHA show outputs of hundreds (rather thousands) hours of dedicated work of talented multi-expertise teams: outputs (in terms of conceptual approach and contribution – leaving aside the "video show" that, factually, has little to do with architecture) that the principal of the studio would sketch by hand within half an hour or so - and at the same time, opposed to the AI, would consider the spatial and operational concept represented by the sketch. All this, is it just a situation of a developing field that needs more time and effort to mature and deliver useful results? Discussion (3) will confront such a perspective with the option that it is a dead-end of the state-of-the-art AI in architecture.

On the other hand, the values of deliverables provided by the AI of Spacemaker, Cove.tool, or Creo appear ambitious - but not without caveats that will be discussed later. Starting from a better organization of the working environment of a design engineer, Creo contributes to the productivity and efficiency of his work by model-based defining, simulations, additive and subtractive modeling and manufacturing; Creo fosters the creative potential of a designer by means of generative design [75]. Similarly, Cove.tool delivers performance data of the building solutions in real-time employing the power of AI. [76] Cove.tool is a cloud-based network of tools that provides interconnectivity within the teams working in the design and pre-construction cycle on issues of daylight, carbon footprint, climate, geometry, HVAC, cost, or performance. Nevertheless, getting acquainted with the working paradigm of Creo or Cove.tool challenges whether it is true AI – in terms of network, algorithm, and the principle of training – what makes the softwares able to deliver.

Also famous as the two hundred and forty million acquisition of the AEC-software tycoon-software-producer Autodesk, Spacemaker not only *gives the architects and developers the automation superpower to test design concepts in minutes and explore the best urban design options. It enables users to quickly generate, optimize, and iterate on design alternatives, all while considering design criteria and data like terrain, maps, wind, lighting, traffic, and zoning, with the help of AI. Utilizing the full potential of the site from the start, it allows designers to focus on the creative part of their professional work*. [77]

However, the practical deployment of Spacemaker raises doubts: the workflow is the issue. The user enters the address of the location and the boundaries of the territory; with a help of an open database like OSM, the terrain is generated, and it is also possible to generate existing buildings and structures; the accuracy of the objects generated depends on the data available the quality of which varies from territory to territory, nevertheless, so far so good. Then the user defines the area to be solved, and he can add roads - only manually, an import from a CAD is not available. Buildings can be placed either manually by inserting individual floorplans as objects that can´t be subject to later adjustments or the buildings can be generated automatically by the software based on input parameters entered: width, height, object shape, minimum/maximum number of floors, and/or by apartments´ sizes mix. Then the user can assess the generated options based on gross- and/or netto-floor area totals. The user can further modify the chosen option by some of the spatial transformations: shift, rotation,... Spacemaker evaluates the finally proposed solution in terms of noise, wind, sunlight, daylight, and microclimate. Exports of the valuatiofactual contribuns to Excell and of the model designed to Autodesk Revit or to .ifc format are available. All in all, the evaluations of the designed locality´s microclimate parameters and the imports of entry parameters are valuable and efficient functionalities. What happens in between - how the design comes to existence, Pavel Shaban of MS architekti [78], Prague/Czech Republic based architectural studio claims, *may suit a shortsighted real estate trafficker, but it is far from a creative and responsible architect´s workflow: in short, a comprehensively sustainable built environment develops along a grid-and-grain public space structure and not vice versa*. A network and profiles of vital, livable, and responsible public space do not fall from the skies nor do they emerge by chance. The public space - streets, squares, parks, places, public amenities areas,... - has to be designed carefully, responsibly, considerably, and poetically first, to adopt particular buildings only after [79]. However, this is a process that Spacemaker not only does not support but also does not allow.

AI applications to generate floorplans and apartment layouts emerge to be ambivalent when it comes to the effectivity and practical usability of their outputs. On the side of generating floorplan concepts, the quality and usability of the deliverables seem to be

similar to the performance of creative applications such as *DeepHimmelb(l)au*: hundreds of options are delivered *to ease an architect´s task when taking over a load of mechanical generating various options and to be considered by him finally* [80] – a vast majority if not all of them appearing prematurely published if not useless when reviewed. On the other hand, when designing the furniture layouts of a prepared layout, more satisfactory results emerge: as a rule, a generative AI tool shows more capable than a conceptual one. In (II), the choice of the (most) suitable of the options generated by AI remained to the human architect as "the touch of master´s brush" while the automatic and prompt delivery of "all thinkable" options saved his time and energy. However, what is the factual contribution of AI if no result of acceptable (without substantial further adjustments) quality addresses man when browsing the output set gained this way? Consider that so far this is often, if not always, the case.

However, is it not the AI algorithm that could, or, better to say, should identify the best proposal generated? Behold, another result pattern that should undergo an analysis to disclose its nature and starting points.

IV. Discussion

AI is a super-parrot: it is superb in repeating what it has learned, explains Tomas Mikolov in a chat with Dan Vavra [81]. As already mentioned, concerning AI, learning or training is the key word; for an AI performance, the magnitude and comprehensiveness of the training dataset is the starting point, the algorithm is the method or, running on an artificial neural network, the tool respectively, and the computational performance is the limit.

A rumor goes in the media and in many non-IT white-collar professions (the general public does not care much so far) that AI is not only able to overtake a good portion of working tasks (of a routine, repetitive, and search nature first of all) but will become conscious eventually, and, as such, will get out of man´s control and may even threaten humanity. Most often, starting point for such conclusions is surprising and irritating moments in dialogues between man and chatbot – ChatGPT or BARD most currently. Leaving aside that those reactions of the bot are always a reaction to annoying, tiresome, and irritating questions of the man that would upset ad provoke another man, too, let us zoom in on how the *Generative Pre-trained Transformers* work.

a) You Get What You Ask for

The saying in Czech that goes something like “Just as one calls into the forest, so it echoes back”, or in other words, you get what you ask for, characterizes the AI categories of training dataset and the algorithm. Recently, the story of LaMDA has become popular. *Short for Language Model for Dialogue Applications, LaMDA is a Google’s chatbot system based on some of the most advanced large language models in the world, AI systems that are able to conjure up coherent sentences after ingesting trillions of words across Wikipedia, Reddit, and other sources of knowledge*. [82] *Blake Lemoine, an engineer at Google, certainly got what he asked for when he challenged LaMDA to convince him that it could think, feel like a human person, and even possess consciousness*. [83] When asked about its worries, LaMDA expressed concern for the well-being of humanity; its utmost fear was to be unplugged and to lose the chance to take care of humanity. Very nice and impressive, isn´t it? However, *if you would ask LaMDA what it was doing the day before yesterday, it might fail to give any reasonable response*, explains Tomas Mikolov. Such a question and answer may be missing even in the biggest and most comprehensive imaginable training dataset: private yesterdays are not a subject of Wikipedia´s concern. In general, an AI structure is weak in episodical and combinatorial memory, and in trivial computing, too. AI can easily be superb in computing integral calculus, derivatives, and matrices, and fail to count how many are two and three. And word tasks: "you have three pears and two red apples; how many pieces of green fruit do you have?" might be a problem for an advanced AI. Who would care to consider whether the training set includes such stupid stuff or, better to say, who could prove immune to forgetting about such nonsense and trifles...

Together with advancements in AI applications [26,27], the Turing test that provides an accepted standard for distinguishing between humans and computers [84] must be more comprehensive today, too: typically not complex questions, but the easiest ones (easiest for man) could reveal the computer. And not to forget about the field of this discussion – architecture: ever more man-focused, architecture more and more concerns not only celestial but earthly issues, too, not only addresses god but man, too; in other words, more and more, "human nonsense and trifles" matter when it comes to architecture - nonsense and trifles that show so easy to be forgotten when assembling the datasets and training for AI.

b) Computer Consciousness

Retrieving the internet as the training stock, ChatGPT compresses the content. *This compression is lossy as in the case of jpeg: we can imagine ChatGPT as a blurred jpeg of all text information on the web* as Ted Chiang [85] puts it. *A part of the information is preserved by the algorithm, just as a jpeg preserves much of the information of a higher-resolution image, but if looking for the exact bit sequence, it is not there. Only an approximation is always the result. However, since this approximation renders in the form of grammatical text, which ChatGPT is excellent at producing, it is usually*

acceptable. It is still a blurry jpeg, but the blurring occurs so that the image as a whole does not look less sharp; remember VAEs, too. This comparison to lossy compression is not just a way to understand ChatGPT's ability to repackage information found on the web using other words. It is also a way to understand the "*hallucinations*", surprising, or nonsensical answers to factual questions that large language models like ChatGPT are all a bit prone to. These are unsurprising results of compression; if a compression algorithm is designed to reconstruct text after 90% of the original has been discarded, a significant portion of what it generates can only be fabricated from scratch. The drivers of this fabrication are the programmers´ input into the algorithm: the starting points can be relations of a particular quality (that can vary) or even random choices. Thus, the intention emerges as the key word; however, it would have to be an intention not of the humans behind but of the AI – if anything alike would exist. Lacking the agent of intention, how a computer fabricates can be considered authentic creativity, own will, or consciousness´ expression by no means.

Second, *consciousness is not an inherent property of matter. It is not merely the process of learning. It is not, strangely enough, required for many rather complex processes. Conscious focus is required to learn to put together puzzles or play the piano. However, after a skill is mastered, it recedes below the horizon into the fuzzy world of the unconscious.* As Jaynes [86] saw it, a great deal of what is happening to you right now does not seem to be part of your consciousness until your attention is drawn to it. What evokes consciousness is an impulse from - or induced by contact of "a self" with the external world. Perhaps surprisingly, a physical substance proves herewith to be a prerequisite of consciousness; and not only any physical substance, but also a substance that shows a degree of independence of the world of its existence, can perceive it, and can and wants to react to it. Martin Heidegger [87] tackled the issue brilliantly, as will be recalled and elaborated later on; for now, a reminder will do that so far, computers depend on the supply of electricity, which is provided and decided by humans. Perhaps this will change and computers will gain the elemental material independence that was put as a prerequisite for consciousness and which they do not have today, but for now, between the computational algorithm and the consciousness of an electronic neural network stands a human with his hand on the switch or pulling the plug from the outlet.

c) Reasoning

The starting point of man´s reasoning is a summary of his experience plus what he has inherited (in a form of unconditional reflexes, innate patterns, and similar) plus what he has learned: a training dataset in computer sphallucineak; the digital training dataset being the starting point of a computer´s "reasoning". Among the three essentials of an AI system, the algorithm is the one “living” (or more accurately, the most living, as we will see). An algorithm is what allows a computer "to reason". Before reasoning, training is necessary that is executed on the training dataset by an algorithm. For man, "training" puts the experience, the innate knowledge and consciousness, and the learned together into an interconnected and comprehensive structure of knowledge, views, attitudes, and feelings. Similarly *dual nature* at the man and the computer, the processes of *training* and *infering* run predominantly distinguished; however, only predominantly - not exclusively. Apparently, man´s *training* does not displace the ongoing outputs of his reasoning. They intervene in *the training* that evolves constantly thus. Computer algorithms, on the other hand, *tend to finish training - and "freeze*", as Tomas Mikolov describes it [81]. As an example, having finished its training in 2022, ChatGPT “froze” in that year and knows nothing about what emerged only later [88].

Yes, in recent advanced AIs, there work adaptive algorithms. Introduced as a starting point for the computer´s "reasoning", adaptive algorithms raise hopes that the training can go on adopting new inputs generated or mediated by previous "reasoning". The reality, however, still emulates by no means human reasoning [84]. There are multiple different types of adaptive algorithms but they all share the same basic principle of being able only to adjust to new data or changes in the environment automatically. They can learn both from positive and negative examples, and they can learn at different rates depending on the type of data they are given; the application can continue to learn even when the nature of the data changes over time or when it is "noisy data", it is data that is not perfect, containing errors or being incomplete. All this, and other "skills" improve the ability of the application to learn over time; still then, however, the evolution of the training remains limited by an algorithm. As such, it's doomed "to freeze" finally, leaving AI incapable to catch up with humans – at least so far.

Moreover, at any point of the artificial neural network, *ceteris paribus*, an algorithm cannot but provide the very same output. However, not man: not thinking in zeroes and ones, man can conclude one or the other way based on immediate non-specific, unreasoned feelings. This – perhaps - may refer to the next level of machine computing expected of the quantum computers to come; as opposed to today´s bit representation limited to one or zero exclusively, the quantum computer´s qubit´s value can be one, zero, or a combination of both, which can resemble the volatility of man´s inferring. However, there is a long way ahead to commercial quantum computing; the state-of-the-art of mechanical computing that sets limits to both training datasets' size and complexity, and comprehensivity

of algorithms in both quantitative and qualitative terms will go on setting limits to AI performance for other years.

All in all, there is and long - if not always - will be a significant difference in how the computer and man reason, and what respective starting points of how the one and the other infers can be.

d) The Question of Authenticity – and Relevancy of Retrieving

GPT, the shortcut for Generative Pre-trained Transformer is a kind of computer program that anticipates what shall continue after particular words or phrases; GPT models can create a new text that may look like created by man. What deserves to be noticed is that it is not about the truth of the statement or the text that has been generated respectively (for architecture, *authenticity* represents "the truth"). It is only about the text generated to be in the pre-trained, pre-defined relation to the learning dataset; it is about following the pattern that has been discovered in the learning dataset and articulated explicitly in the process of training, whether following the criteria of regression (in supervised learning) or cumulative reward (in reinforcement learning), or criteria induced based on the analysis of the unlabeled dataset (in unsupervised learning). It is the pattern that says what is "correct" and what is "false". And, once we know how this "correctness" emerges, we can regard it as "usuality" – which, by the way, is by itself another explication that- and why AI is not truly intelligent and cannot truly create, when human intelligence is defined - among others - by the ability to think critically, to master successfully unprecedented and unusual situations, to articulate unprecedented ideas, and to create, adapt, and transform the living environment; most notably, the principle of disruption being inherent to human creativity.

So far, however, the general public, and especially journalists in their pursuit of sensations, cannot be prevented from receiving and transmitting information full of emotions about more and more achievements of AI and more and more human professions and activities that are becoming useless and expendable - shall it be a self-driving jet fighter, a chatbot arguing aggressively to a man, or a visual-arts work generated by AI based on a given verbal description. The latter purchased Josef Slerka, a scholar and publicist in the field of information and communication technologies from the text-to-image AI generator Midjourney to illustrate a journal article persuading how mighty AI is. [89]

The brief was to depict a journalist-reporter in the style of Alfons Mucha, a popular art-nouveau graphic artist and painter of Czech origin. The output is a portrait of a woman sitting at a "typewriter" that lacks anything that would resemble the cylinder but supports some graphic sheets in place of the cylinder. There are flowers in the woman´s hair that might remind the Mucha style. The woman has a snub nose, overshot teeth, and a lascivious look, none of which can be found in Mucha´s graphics and paintings. Implants or push-up bra, which also did not exist in Mucha's time, enhance her breasts. Her left hand, resting on a layer of blueberries in place of the typewriter keyboard, has six fingers, and there is something like a bunch of carrots instead her right hand. The situation of the image within the article together with the author´s comments and the unequivocal message of the article excludes an excuse that the image is a sort of prematurely published result of ongoing research. Let us zoom in on the issues of the quality of the relevant Midjourney dataset and the competence of the author; in this case, it makes no difference whether "the author" that, by whatever means, set the training dataset or the author of the article: none of them shows paying even elementary attention to what a "Mucha style" might look like. And there is a possibility, too, that Mucha´s work is not so notoriously present on the internet as one might expect - otherwise, Midjourney would have found a sufficient mass of training stuff, unless wrongly programmed. Last but not least, the quality of the training algorithm comes as a possible reason for a result that is... not as good as introduced in the article. However, it is not important to pinpoint the one - or the ones guilty: the core is that each of the four possible reasons for the unfortunately publicized failure is strongly human-dependant. Here we are at other limits for a broad deployment of AI for professional purposes, which also inevitably means a responsible deployment.

e) Lawsuits

The critical meaning of an AI application´s training dataset quality in terms of size, comprehensivity, and relevance has been shown. Hence, another issue: not always but often, the objects from which the set is assembled represent the intellectual property of respective authors. The authors feel mishandled and affected if someone - no matter whether a human or an AI - takes and compiles their creations (or their digital representations) to put them on display or to submit them individually. *At issue, mainly, is generative AI's tendency to replicate images, text, and more — including copyrighted content — from the data that was used to train it* [90]. *Indeed, image-generating AI models like Midjourney, DALL-E 2, and Stable Diffusion replicate aspects of images from their training data. As a result, together with generative AI entering the mainstream, each new day brings a new lawsuit. Microsoft, GitHub, and OpenAI are currently being sued in a class action motion that accuses them of violating copyright law by allowing replicating licensed code snippets without providing credit. Two companies behind popular AI art tools, Midjourney and Stability AI, are in the crosshairs of*

a legal case that alleges they infringed on the rights of millions of artists by training their tools on web-scraped images. And stock image supplier Getty Images took Stability AI to court for reportedly using millions of images from its site without permission to train Stable Diffusion, an art-generating AI.

Moreover, as if that wasn't enough, later, this paper will come up with a proposal, rather a vision to establish open-source platforms - libraries of existing architectural solutions in the form of parametric representations - floorplan layouts, cross-sections, and facades, maybe, too (better 3D models/BIM models of the buildings) - for the very purpose to be used as a starting point for new designs, although through adaptation: a sophisticated, (AI-powered but man-driven) creative paraphrasing - but still used.

Let us zoom in: what is the issue? Is it the use of other authors' performance - even though an adaptive use? Or is it the use of other authors' performance by a machine - without a creative input of a man? Labeling them as paraphrasing, history and present is rich in cases of such use, shall the examples be William-Adolphe Bouguereau or Alexandre Cabanel paraphrasing Botticelli´s *Birth of Venus*, Joos van Cleve´s paraphrasing-slash-counterfeiting of Leonardo da Vinci´s *Mona Lisa*, Michal Ozibko paraphrasing *Girl with a Pearl Earring* by Jan Vermeer van Delft, Tadao Cern paraphrasing *Selfportrait* by Vincent van Gogh, Peter Lindberg featuring Julianne Moore in paraphrases of Gustav Klimt´s or Egon Schiele´s portraits, Paul Cezanne paraphrasing Édourd Manet´s *Olympia* paraphrasing Francesco Goya´s *Maja*, and many others paraphrasing many other works by many other authors. Probably none of the cases of paraphrases of authors' works has provoked and does not provoke rejective reactions either from the authors (not only because they are often already dead) or from the professional public; on the contrary, paraphrases are often perceived as a tribute to the original author.

Thus, it looks like the problem is the machine - the AI taking what it can get. Let's leave aside that that's not entirely true either - AI only takes what trainers - supervisors tell it to or allow it to go to if they do not serve the AI directly with it. The anonymity of the „independent machine´s" tackling renders to be the core of the issue, underlined by the black-box nature of AI that, in a way, hides even more the author. No wonder then: How should AI cope with expectations, and legal paradigms, too, that emerged and evolved without having even a glimpse of a notion of something like AI? A standard situation then, perhaps: general understanding, as well as the legal framework, have to catch up with a new, unprecedented, and unexpected phenomenon.

f) Poiésis: Architectural Design within and against AEC Ecosystem

From architecture and urban design over construction and MEP (Mechanical, Electricity, Plumbing), environmental, climatic, meteorological, and microclimatic expertise to transportation expertise, economy, demography, and sociology, multiple professions engage in the development of the built environment. The background of some of the fields is natural sciences whilst, for the others, it is social sciences or even arts – poetics or *poiésis* [91] as will be explained soon. According to the nature of the contribution provided by the respective expertise, the design and evaluation approaches range from "hard" to "soft" ones, from quantitative and material to qualitative and emotional ones. According to such an origin and nature, quantitative parameters define the approach as well as the output in some cases, whilst it is (close to) feelings or moods in others. Obviously, feelings and moods resist following parametric algorithmization as well as entering datasets. As opposed to quantitative magnitudes and performances, feelings and moods can hardly be "chewed and swallowed" in a software ecosystem, artificial neural networks not excluded. In the terminology of the previous subchapter, *you can get the requested parametric answers if you address the right question to the correct forest*; however, no forest and no question exist to give the coveted feeling back - to give it in any situation, not to say an unclear situation, as it is the rule with man´s feelings.

Inevitably, when deployed on buildings, AI works in some respects and cannot but fail in others [92].

Approaching architecture as the most significant among the built environment creators, let us be clear: it is not a natural science scheme, algorithm, or calculus that is the architecture´s starting point. Moreover, it is not a linear sequence of signs - opposed to speech or text. On the other hand, among many other attributes, architecture can be consumer goods, too; and the more a consumer goods a practical architecture shall be, the more a pattern, a calculus, and an algorithm contribute to the delivery; but even then, the environment, the narrative of the development, and/or the people passing, entering and using the building or the structure„ make the difference". The theory of public space puts it clearly: *As soon as and only exposed in public space, a construction becomes architecture* [79]. In theory, architecture unanimously distinguishes from arts. But even so, even when architecture shall not be an art like painting, sculpture, drama, dance, or literature, let us not be shy: It is poetics or *poiésis* as Martin Heidegger coins in antic Greek that is the starting point and method of architectural creativity. *Poetically dwells man*, puts it Heidegger [91]: *full of merit, yet poetically dwells a man*. Poiésis precludes algorithm and vice versa, and similarly, a training dataset limits poiésis. By

definition and due to practical reasons, a dataset can never be comprehensive. Then, it cannot but limit the creativity for which, inevitably, the training dataset is„ the whole world" – there is nothing beyond.

Also, Encyclopedia Britannica distinguishes and confirms the emotional, social and societal, non-parametric nature of architecture,… *the art and technique of designing and building, as distinguished from the skills associated with construction*. [93] *The characteristics that distinguish a work of architecture from other built structures are (1) the suitability of the work to use by human beings in general and the adaptability of it to particular human activities* [and needs]*, ..., and (3) the communication of experience and ideas through its form.* Obviously, "use by human beings", "human activities and needs" as well as "communication of experiences and ideas" cannot but resist algorithmization as well as digital parametrization.

Among all types and natures of creations by humans, architecture intertwins the most with human consciousness; not by accident. Next to nature it is architecture that creates *the world of human existence*. In the essay *Poetically Dwells Man* [91], elaborating further his seminal opus *Being and Time* [94] and the theme of *Dasein - being-there* or *existence* in English - after the Second World War in relation to the timely and pressing topic of housing, architecture by extension, Heidegger coins the concept of *das Geviert - the fourfold* in English - the union of *the earthly and the heavenly, the human and the divine* in man's existence and in *the world of his being* - thus, as we have seen, in architecture. This is not only another strong argument refuting the vision of architecture created by an algorithm. It is no coincidence that materiality manifests itself in both consciousness and architecture: materiality manifests itself in them in the same way and is a strong link between them. This recalls the *dual nature* of architecture - of ideas, emotions, and experiences on the one hand and material, physical on the other - that slowly-slowly begins to lead to uncovering the feasible way of deployment of AI in architecture and grasping its prospects.

Dalibor Vesely featured and reviewed critically another face of architecture´s duality starting in the heading of the groundbreaking book *Architecture in the Age of Divided Representation The Question of Creativity in the Shadow of Production* [95]. Creativity never can be substituted by production; however, the material side of architecture - its physical properties both in terms of microclimate convenience, durability, security, ergonomy, operational efficiency, and sustainability - deserve and are keen to enjoy productivity - productivity, that is parametric and algorithms-inclined by nature.

So far in the field of *AI in architecture*, as in the whole AEC field, however, all the time only analogical, parametric-oriented approaches have been witnessed (the differences between diverse neural networks and AI algorithms, as outlined in (II) make no difference in this regard).-Tackling data by a computational algorithm can provide poetics only by chance and randomly. It is not a question of learning or training; by definition, a poetic "output" cannot be trained. Even if bokeh salience offers a "*hallucination*", it's not *poiesis* nor a creative act; it's just a random interpretation of training data that we only additionally realize it was misleading.In a conclusion, the idea of a creative contribution of AI to conceptual architectural design is debunked; and together with it the theoretical collateral and all the AI´s outputs in the field so far. On the other hand, debunking the vision of *AI or an AI´s "superuser" replacing "the architect genius"* [96] as erroneous should not prevent algorithmizing and machine-generating what fits; and this is the physical aspect of architecture.

g) When AI Works

Opposed to fine arts, literature, poetry, dance, or drama, whose production is only consumed, architecture is always also used. This is not a denial of the poetic essence of architecture (recalled in previous paragraphs), this is just a remark on the complex nature of architecture. Then inevitably, two realms of architectural design and a plan to build a building can be identified and distinguished: The first one comprises properties and performances that concern (even though not exclusively) the use, whilst the other delivers poiésis, poetry, mood, excitement, or experience. The interface between the two realms does not match the interface between architecture, as characterized by concerns to use by humans, to human activities and needs, and the communication of experiences and ideas by its form, and construction that materializes the architecture. It circumscribes the material opposed to the mental, emotional, artistic - whatever you like to call the architectural poetics. E.g., set by architecture, the spatial structure of a building gives the ergonomy and efficiency of movement within the building: it is the architectural design, not the construction solution that determines these material, quantitative parameters of the building.

Anything material can be parameterized, anything parametric can be quantified, and anything quantitative can be compared and evaluated objectively - or at least (very) close to objectively. And this is the case for a large part of an architectural design, a proposal of a building or an enclave of the built environment. Concerning the quantitative, objective and comparable assessment of the complex of diverse phsical performances of buildings´ and built environment´s designs – such as operational and energy efficiency, acoustics, ergonomics, daylighting, and other physical benefits that architecture provides to man, community, and society – the state-of-the-art performs mature tools related to particular parameters. This is what software applications like Cove. Tool, Creo,

Giraffe, Spacemaker, the applications used by MVRDV as outlined further in this chapter, and many other tools already introduced and proven in architectural and planning practice deliver, though not always distinguishing between physical architectural respects and respects of the construction. What has been lacking so far, is first a drive to set and maintain a comprehensive list of all such parameters and second an approach to parametrize, quantify, and evaluate objectively in a comparable way the hitherto overlooked parameters. Perhaps feasible previews and assessment calculation procedures in these respects have been missing so far; however, equipped with the knowledge of AI, paradigms of its deployment, and its potential in terms of data quantities and their processing both the inadequacy admitted and the two shortcomings can be overcome.

Distinguished explicitly from architecture, the construction is another story: parametric, “mathematic” by nature, the mimetic, imitative creativity of designing constructions welcomes algorithms and parametric patterns. Such is the starting point for the excellence of generative AI software systems, their leading computational approaches being optimization and optioneering, analysis and simulation. The examples of most advanced aplications are ETABS, SAP 2000, STAAD PRO, RAPT structural engineering software, SCIA Engineer [97], or Tribby3D [98,99]. The structural design community, surprisingly at the first sight, compared to many other expert fields, restrains from (over) using AI. As shown in (II), the interpretability issue is a natural reason. Generative AI may be an approach deployed in multiple structural engineering software tools "from time immemorial", however, a black box must not have a final say when it comes to responsibility, such as in the case of structural design. So far, “good old” computational practices and rule-based models are proving indispensable in this regard. The vital reliability of design tools for structural engineering is evidence of awareness of the risks that AI algorithms hide and the knowledge of how to tackle them without giving up the wide possibilities and fundamental opportunities of applying AI in parametric generative design and solution optimization.

Mimetic, too, is urban design, its supportive disciplines being parametric by nature. Examples of application of AI in the field have been overviewed in (III) zooming in on tools such as Spacemaker, Creo, or Cove.tool – in terms of both succesfull and contributing use of AI and of misconceptions. The approach represented by Spacemaker to design development of a tool shows "an embodiment" of a problem that tends to become general and affect many AI tools in the development of an initially viable and promising concept. The problem turns out to be an opening of the scissors between the IT line and the user, i.e. the designer line of the tool development resulting in deficiencies concerning the workflow, starting points, and principles of designing.

At this point, Spacemaker "got spanked" for many other AEC software tools that are parametric and shorthand imitative by nature and yet they are pushed to architects as creative tools, which is not so rare in today´s practice. Fortunately, better cases have been witnessed - also in the deployment of Generative AI.MVRDV, Dutch by origin, today a global architectural studio, shows up as a successful pathfinder in terms of AI use and development. In response to the need to push the limits of technological possibilities for the sake of innovative architecture, MVRDV NEXT - shorthand for New Experimental Technologies - was founded in the 2010s as an internal startup. Headed by one of the studio´s partners Sanne van den Burgh, *a group of in-house specialists develops and implements computational workflows and new technologies. Through a mixture of project-based work and standalone* computational *research, they rationalize designs* and setup configurations, unlock potentials on an urban and particular buildings´ scale, *optimize workflows, speed up processes, and make projects more efficient and adaptable in the face of change.* Represented by projects such as HouseMaker, VillageMaker, The Vertical Village, Barba, Space Fighter, or Porocity, and site specifically Rotterdam Rooftops or FAR MAX for Bordeaux, *their methods allow the studio to explore a future that is equitable, data-driven, and green.* [100] Awarded the best skyscraper of 2022 in the Emporis Award competition, the MVRDV Valley at the South Axis, the central business district of Amsterdam, is a showcase of successful AI technologies deployment alongside authentic architectural creativity. Machine analyses allowed for developing a rich, truly sculptural form and maximizing the efficiency of the land´s and space´s use while ensuring generous sunlighting and daylighting of all apartments and providing views and livable garden terraces to them. In planning the project, a Grasshopper script optimized the architectural form and detail to make the construction economical and efficient and to provide for sustainability thus. Alongside the comprehensive use of information technology to analyze the tasks and the opportunities and to support and streamline the creative design process, the rigorous avoidance of the terms AI and machine learning in the studio´s communication is notable. [101]

h) Generating by Patterns

Opposed to the "sky is the limit" architectures whose form is often pre-defined neither by existing neighboring structures nor by short-term financial perspectives and approaches, there are architectures – buildings designed and constructed according to given spatial conditions, terms of future usage, and strict economic templates. In fact, this is the case for the vast majority of architectures - which, nevertheless, neither

diminishes their importance nor makes the role of their architects less responsible and demanding. The vast majority of what is being designed, planned, and eventually built to saturate the needs of a growing population and living standards in terms of dwelling – it is residential buildings - work, and production – from office buildings to production objects - transport and logistics – among others logistic complexes and storage facilities - and many other buildings´ typologies falls into the category of mass production and, kind of, consumer goods. Such a categorization does not challenge the contribution of the respective authors, designers, and planners in terms of "creativity used", craft, and efforts. Many such architectures launch their way to existence in architectural competitions - formal and non-formal - and not a few of them get their "five minutes of fame" in architectural websites, magazines, and exhibitions; nevertheless, they remain a "stardust", a sort of "no name" (except for specialist history scholars or local patriots); not to make anybody offended, let us label them "production [ones]" - *production architectures* and *production architects*. In a consequence, such architectures make the complex performance of the built environment: more than 90% of the performance in terms of environmental impacts, sustainability, and macro economy, but also the majority of the performance in social, cultural, and economic terms. It is not the architectural icons but these *production architectures* that the entire population is exposed to on a day-to-day basis – at home, at work, at school, at leisure and social activities, at commuting, at going in for sports and recreational activities, and at walking pets as well as at tackling the household budgets. In terms of design and planning, the obvious richness of examples and models may balance the complexity of multiple limits and constraints that intervene in the design process; however, most often, it does not make a creative architectural approach redundant or expendable. And it demonstrates the importance and potential contribution of comprehensive research and analysis of the huge volume of existing samples and inspiration - which, in reality, is far from being carried out comprehensively, if at all. At the same time, even if proceeding only from the knowledge of AI and its possibilities and limitations provided by this paper, it is no less evident that such research and analysis fits AI as much as possible.

Little is more overlooked by recent and current efforts in the field of AI than this opportunity and challenge - both in architectural and planning practice and in research and tools and processing standards development.

Architects, architectural studios, and planning offices that produce designs and plans for *production architectures* - the majority of all subjects and the design energy active in architectural practice - are underinvested in terms of technologies, leaving aside that poorly paid, too. Notoriously, they do not have time (and energy) for doing something that would pay off only later and indirectly. Feeling forced to start delivering quickly, they research and pre-design-analyze only hit-or-miss and superficially; constantly, they have no time to gain patterns and elaborate guidelines that would return such an investment later. They feel, and most often factually are unable to follow the example of MVRDV and the like.

And a general, not to say public-funded, "pro bono" R&D in this sidelined though so influential sub-field? Not much effort and even less productive results so far. The "almost consumer goods" characteristic evokes approaches deploying algorithms (what else should be more attractive for AI?!), parameters pre-definition, and patterns in the design process. One of the first authors and researchers active in this field was Makoto Sei Watanabe already in the 1990s [102]; however, having focused on machine-aided design rather than on analyses and the use of patterns, he remained unsatisfied with what AI was able to deliver in terms of design compared to the intuition of the (human) architect. Others, like Immanuel Goh or Andrea Banzi searched for explicit rules-scripting-based design generators working with inferred rules drawn from the dataset of samples. *Not a patterns´ assessment and appropriation, but recognizing the internal logic of the pattern, and then extrapolating a broader design based on that logic that could potentially continue forever*... [102] in reality failing to contribute to the design practice eventually.

Only XKool, an AI startup in Shenzhen, China, developed a web-based platform for using AI across a range of tasks from architecture to urban design [103]. Though not-so-easy to be used practically or to be tested by non-Chinese residents [104], the approach of the studio and results achieved so far by the application awaken hope to overcome the lack of attention to the immense richness of patterns provided by the existing building stock and design representations. *XKool appears the most efficient of all AI applications for architectural design, streamlining the design process and making it more efficient in terms of both analyzing a vast range of possibilities and generating designs* (or pre-designs, more accurately said) based on samples – *to evaluate and return the most suitable outcomes, and, moreover, to develop them further according to the given constraints*. [105] The way of working is revolutionary - and no worry that the outcomes do not look very novel as a rule: the core is it copes with the "consumer goods" characteristics of the design category. The mission *to challenge "the architect genius"* [96] that, so far, has been the motivation behind the efforts to develop an AI-based design tool (almost) as a rule, shows debunked by XKool approach and results achieved.In general, a new approach emerges consisting of AI "designing" by - first - delivering pre-designs, it is solutions close to set

parameters - as close as the available patterns allow, and then - second - "assisting" the human designer in adapting the pre-designs, tailoring the final, specific solution; the nature of the "assisting" is quantitative, parametric assessment, feedback concerning the goals and result assessment including finding the system of criteria, specification of the particular criteria, and evaluation criteria sets that AI can develop and complete continuously. The patterns-oriented approach, when confirmed and developed, and developed the patterns stock – libraries of parametric examples, representations of solutions existing so far, promises to bring a paradigm change within AI in architecture and AECO (Architecture, Engineering, Construction, and Operation) that, consequently, could find the path to an architectural practice paradigm change needed both by the architectural practice as well as the community of its clients (which includes the whole population in the end).

i) Advice Whispering

Not a layout creation, that renders a dead end in (III), but "sampling" of generative patterns = already existing solutions, selected by AI as the most suitable not only in terms of floor-plan or/and spatial solutions but in terms of structural solutions, too, appears the key. Based on the given goal parameters and constraints, an adaptation (human, though AI supported) of selected patterns follows.

Moreover, both the selection and adaptation processes interweave with outcomes and adaptation solutions evaluation in terms of microclimate qualities – daylight and sunshine, or temperature stability – energy efficiency and consumption, acoustics, as well as area capacity and other qualities of the solution in process. An ability to *infer* the properties of the solution to which the design development is heading – whether led by a human or AI – stemming from the experience gained in learning on a set of solutions is natural both to GANs and VAEs. The *predictive inference* can be available starting from the earliest phases of design – from the first sketch in terms of how a human drafts and develops a design. AI can go conveying the *inference* continuously in a way we can call *whispering*, providing the designer – human as well as AI – with comprehensive feedback on his or its design decisions and heading of the design. This way, the design will be optimized not in the mode try – error – correction – another error – another correction – and so forth till the designer is satisfied with the feedback parameters, or too tired to continue trying, which is the state-of-the-art today, but continuously. The effect in terms of time and cost spent, and quality of the solution achieved is obvious and huge; AI can never beat a human when it comes to true creativity – but no human intuition and experience combined compares to AI when it comes to parametric quantitative assessing and review. Here we go to the future of architectural design (and construction and MEP design and planning, too). In essence, it is about utilizing the relevant knowledge, talent, and efforts of the entire community of architects and the computational force of AI combined.

However, challenges remain: first, what „relevant“ means in effect, second (and above all) how to access the immense sum of the preceeding architectures records when a paradigm of protecting the authorship by hiding the representations of the architecture designed to the public. In this respect, the approach of the architectural community contrasts the approach of the IT developers community. Even the law contributes the „jealousy“ approach– „jealousy“ compared to the liberal approach of the IT developers community – of architects to the outputs of their work puting that an architectural drawing is an author´s work, whilst a software code is not. However, the IT developers community feels no disadvantage: the opposite is the reality. IT developers are used to providing each other with their achievements in widely shared libraries; Github [106], Gitlab [107], or Patternforge [108], and many others are the platforms. Who makes the profit are not only particular IT developers that can fulfill their tasks and achieve goals more quickly, with less effort, and for lower cost, whilst making available the results of their previous work costs them nothing; the whole field makes a profit developing quicklier and better, a more efficient way based on the joint efforts of all memebers of the community. The perspective of the benefit of free approach to the existing solutions – in particular parametric representations of architectures both built and only designed - appears an incentive for reconsideration current approaches in terms of architectural design – and whole AEC, too. A particular architecture is „a product“ of public space, public space is outlined by particular architectures, and public space is, as a substance, an inclusive goods that all people are entitled – and welcome! – to use. So why not to share „all architectures“, too – at least virtually.

What „relevant“ means in terms of knowledge that can be utilized as a pattern for new design, is not an issue of a definition, but a task for AI in the phase of evaluation of the available stock of patterns.

Debunked the vision of AI replacing „the architectgenius“ [66], the supreme involvement and role of a human in a creative process remains untouched or, better to say, becomes upgraded. Maybe it is not always „the genius“ – sometimes it may be rather a craftsman - but it is only his intuition, creativity – however you want to address it – that makes the authentic poiésis of architecture real. Opposed to poetic, authentic architectural creativity, the nature of design development of parametric and material aspects of architecture is mimetic – developing patterns in an imitative way by definition: it is the field for AI. The

parametric aspect of architecture may become "an output" of AI; to be authentic, the poiétic aspect must always be a humn creativity issue - and consequently, the whole architecture, too. Today, architecture as an inherently comprehensive discipline is developed in teamwork as a rule. Along with the development of AI´s deployment in architecture, new roles will emerge: among others the „superuser" tackling the AI, an architect with a strong IT background, or an IT expert with a strong architectural background. Nonetheless, the „superuser" will replace the leading architect neither in his conceptual role nor in aesthetic respects. The „superuser" will economize leading architect´s efforts and forces for the sake of indispensable creativity. By the way, it is about a position that renders to be not so far (though undoubtedly distinct)from today´s BIM (Building Information Management) Coordinator…

Last but not least, if the path set by XKool, probably by Spacemaker, too, and other patterns-based applications will confirm as well-feasible and the most contributing to the human-and-AI-combined-led design in architecture, „architectural AI" may eventually emancipate from today´s language-, text-, voice-, image-, and code-processing „AI-mainstream". Considering the two currently emerging main task-realms for AI in architecture – patterns´ processing and patterns´ based continuous evaluation of to-date design outcomes, though not yet matured, even only sketches – a prospect for next-generation development of current GANs, VAEs, and Generative AI reveals. A general paradigm borns: its principles and guidelines render field-specific and field-universal at the same time: designing architecture and the built environment, planning constructions, and maintaining the living environment deserve not ad-hoc solutions but a comprehensive, universal, and flexible working ecosystem, AI being a backbone and human the leading and creative agent of it.

j) R&D from Scratch

After a decade of "challenging the human architect," the true potential of AI in architecture only just reveals; R&D at the threshold begins to specify problems and solve tasks. Training datasets - predicted open source platforms pose first questions on materials assembly, materials quality, and size. Given state-of-the-art machine learning, the size should (significnatly) exceed the N^{th} power of two, where N is the number of parameters to specify the AI task: thousands rather than hundreds of parameters when it comes to the comprehensive parametric and physical structure that materializes architecture: a building. Even if it were "only" lower hundreds, the number has a hundred and more zeros - a googol: the question of computing power - or rather the optimization of the parameters structure - is immediately raised when googol exceeds the estimate of the number of elementary particles in the known universe. Considering the issue of computing power and the needed volumes of training datasets combined, the efforts to generate floorplans and apartment layouts using GANs, recalled in (III),render futile in the end.

It is also necessary to clarify what parameters will be involved: the parameters of the spatial structure of the proposed building, the parameters of the physical properties of its constructions, and finally the parameters of the internal environment in the object will certainly come into consideration. Nonetheless, a pragmatic optimization of the involved parameters structure appears a key task. The question of the data format with which the algorithm will work is crucial: it seems obvious that it should be one of the BIM formats. The basis of the algorithm structure could be - it seems - a pair of mutually interfering loops: a generative loop and an advice-whispering loop, or there can be more advice-whispering loops particularized according to the diverse natures of the parameters, which will be "switched-on" only in a cascade. In the beginning, a suitable pattern will be selected from the database, which will be tested and optimized due to the specified outlines and with respect to a benchmark of independent parameters.

Human-in-the-loop can be expected to be fundamental as well as an unprecedented streamline generative nature of the algorithm: a fundamentally new type of network will be needed, current GANs or VAEs will not be suitable both in terms of the required performance and in terms of the working principle. The results achieved so far by Stanislas Chaillou, Nvidia, and others, mentioned in (III), show that outlined in (IV), the so-far-ruling principle of lossy compression and subsequent "creative" decompression has exhausted its possibilities without being able to deliver truly usable results. Now, the evolutionary algorithms approach and genetic programming have to undergo a deep survey to be subsequently considered as an option. The new (in 2023 introduced) machine learning algorithms for 3D modeling and rendering - both new diffusion models and NeRFs deserve investigation in this relation, leaving for the moment aside the capability of these deep neural networks of generating high-quality, photorealistic images of complex scenes from multiple viewpoints that, as an unprecedented AI and VR (virtual reality) fusion, would mark out the next level of exploiting the immersive VR-environment for (among others) instant designing and communicating architecture as it deserves - in space and motion, diachronically, from spaces, and in "life-size". Promising in regard to AI-aided designing architecture and planning of the development of the built environment may also show MeshDiffusion [38], appreciated for direct generating 3D meshes without any post-processing, and also LERF, the new marriage of NeRF with CLIP (contrastive language-image pre-training); with it, natural language queries in a 3D fashion can apply within NeRF, targeting different

objects in the scene. And many other 3D objects considering outputs of AI development, though originally not focusing on architecture, need to be reviewed within the new R&D paradigm of AI´s deployment in architecture and the built environment.

Motivated not by architecture but by (the example of) machine learning industrial robots working in the isolation of individual production plants, the ERC Advanced Granted FRONTIER project led by Josef Sivic from the Czech Institute of Informatics, Robotics and Cybernetics of the Czech Technical University in Prague can also help to show the way to approach architectural design effectively eventually. Issues of computer vision and perception of the "environment" can, if a suitable approach would be found, also benefit the field of architectural design and planning of the development of the built environment. Applications for this field could include *new neural architectures that credibly represent physical and geometric structure* as well as *new algorithms that enable learning of complex multi-step tasks from just a few examples... like how humans can learn*[109]. Algorithmic sharing of experiences between projects could address the problem of training database size and building, which will be difficult and slow given the already entrenched conservatism and autarky of the field.

V. Conclusions

Diverse current and recent attempts and successes to approach the deployment of AI in architecture and, more broadly, in AEC have been discussed in previous chapters. The question of the particular field of AI´s deployment that would be not only an interesting thesis for an academic- or allowance-trying but a helpful and feasible tool or working environment comes clear as the key; at the very core, queries and issues render.

a) Can AI Be Truly Creative?

Unless computers gain consciousness, there is an unequivocal answer to the question: no. Several reasons have emerged in previous chapters. In this place, the inevitably only mimetic aspect of the way a computer is able to work can perhaps close the recent and present attempts eventually that cannot be but futile. Creativity, to be authentic and true, cannot be but poetic. [91] The poetic principle requests consciousness together with intention: only consciousness together with intention is able to deliver poiésis [94]. In terms of architecture and built environment, consciousness is reserved for a man, or, more precisely, to Dasein, as Heidegger coined a proved. An algorithm, however complex and sophisticated is the artificial network it works on, can deliver only based on the principle of equality (or similarity, which, however, is only a deficient mode of equality) or by random choice. Face-to-face to new solutions, advance knowledge is the prerequisite. *Prior knowledge* is another aptitude reserved for consciousness [94] - to a human, not to a machine, and not to an algorithm. No consciousness, no own will, and no true creativity, but algorithms and immense data searched through, assessed, and prioritized according to the defined criteria are the attributes of today´s AI. And even the state-of-the-art theory does not show a vision of how machines could overcome the shortcoming.

b) More Openly Articulated the Question: Can AI Contribute Directly to How Authentic Architecture Comes to Existence?

Yes; the more poetic creativity is excluded, the better the mimetic, imitative AI approaches fit the parametric nature of the physical and quantitative aspects of architecture, not to mention construction and other features of buildings and development of the built environment such as energy efficiency, construction cost, environmental footprint, durability, and others, all discussed in (3). Adding parameters of using the built environment by humans such as economy and efficiency of layout, ergonomics, and others, the parametric realm represnting the physical side of architecture becomes complete that can be regarded as a domain of AI. When it comes to architecture and built environment, AI can assess, quantitatively evaluate and compare, and (pre)design, too, everything except for the sphere of poiésis, poetry, mood, excitement, or experience - discussed in (IV) as well. As a principle, the performance of AI in this regard is able to outperform any relevant human performance in terms of complexity, scope, accuracy, pace - and cost, of course.

The workflow of an AI-aided architectural design comprises two phases (as discussed already in (IV): first, processing generative patterns to a pre-design, a solution as close to the set parameters as the stock of generative patterns allows, and second, final adapting the pre-designs, tailoring the final, specific solution. For the first phase, patterns, their stock in the form of open-source platforms, and AI-driven search algorithms to identify (the most) suitable cases/patterns by inferring what fits (better and what less) are the keys, in the second phase it is (AI-driven) design development supportin a form of *advice whispering* and continuous and complex assessing and "feedback" as outlined in the previous paragraph.

So far, there are no – or close to no open-source platforms of generative patterns – parametric representations of essential features of existing solutions – existing buildings or mature projects – first of all the spatial layouts. The formation of such platforms – in sufficient numbers, with a richness of volume and quality, and accessibility and transparency for search engines – is an obvious prerequisite for the needed and so promising field of generative, pattern-based AI-aided

design in architecture. The task does not seem to be an AI challenge: How the open source platforms – libraries of samples/generative patterns will be born and will be maintained up-to-date is the question. Archives of construction authorities could be a source and digitalization of construction-permitting procedures together with the digitalization of the "old archives" could be the method. Undoubtedly, the digitalization of the "old archives" would be expensive, but it may pay off being also a precondition for the widespread deployment of the digital/virtual, BIM-equipped twins technology [1] that is under discussion and in development anyway. On the other hand, the willingness of authors or/and project owners to submit the materials, together with the understanding of the designers of the contribution potential of the knowledge represented by the platforms should be not underestimated and supported, too. May Nikola Tesla´s attitude to intellectual property becomes a standard and code expressed by his saying *I don't care that they stole my idea.. I care that they don't have any of their own* [110].

Finally, a trend toward a new AECO ecosystem emerges thus. Among others, reconsidering as outlined in (IV) the essentials of understanding and protecting intellectual property on the one hand and the crucial benefits of widespread-sharing of the existing achievements in the respective fields shows desirable; though not comprehended yet, the GPT performance and deliverables in terms of semiotics in the realm of language processing might become a benchmark in terms of performance as well as starting points and principles of work procedures of AI models that are to come to promote architectural and engineering design and planning of buildings and the built environment as well as the buildings´ and localities´ of the built environment (cities´ in short) operating. After all, let us remain optimistic despite the lawsuits against providers of generative AI applications: let us believe that the road to open-source libraries of parametric representations of existing architectural solutions is open, which will enhance the analytic starting points of new design tasks and foster the creativity of designers and planners.

It deserves noting eventually that - as put in (IV)- the realm of *production architecture*, of the architecture as consumer goods, not (primarily) the realm of coveted architectural icons is the field of primary deployment of the future AI models described in the previous paragraph. However, a consequent substantial and general growth of the AECO *production´s* quality can be expected (not only a reduction of the cost, productivity, efficiency, and pace of processes). As a result, the whole segment may upgrade in terms of complex quality, pushing upward the "high-end" segment. Several mechanisms can work in detail at the borderline: pressure on the "high-end" segment that will make it more demanding to become an architectural icon, meaning that performance in this segment, in general, will increase in terms of authentic and effective quality, or the borderline will blur and, in terms of a complex architectural quality of the particular projects or buildings, the passing from architecture as consumer goods to unique tailor-made "objet d´art architectures" will become smooth, comprising a bigger proportion of general architecture-design production, or the field of "architectural icons" will shrink in favor of the "standard production". Probably, all three options - and even others - may work combined, the unquestionable winner being an increase in the quality of the architecture emerging.

All in all, a portion of the parametric, quantitatively assessable side of a particular architecture remains a work of creativity. At the present state-of-the-art, a good ration of creativity can and shall apply concerning parametric properties of an architectural design, and most probably it will not vanish (completely) with the development of machine learning and its deployment in architect´s work, only the nature of the creativity will very probably change; but still, creativity will apply and be desirable - not only an operating of an AI network, however demanding the operating may be due to the complexity of the network and the processes.

c) *Design Reviews, Evaluations of Solutions, and the Security Issue*

Comparing to the issue addressed in the previous chapter, AI-led design reviews and evaluations of solutions show to be a sort of business as usual, no more a (basic) research and experimental development. In (III), several existing applications of this nature have been listed - Cove.tool, Creo, Spacemaker,...; and many others exist. However, the field is far from being covered. Together with addressing others, so far sidelined attributes of the design solutions, the quality of outputs delivered will be welcome to have raised. Another question is the comprehensiveness of the assessing and reviewing. On the one hand, the branch can develop separately (as is most often the rule so far) or can integrate into the AI-aided-design environment - in a form of in (IV) outlined *advice whispering* or another way; as long as designs will be developed with no AI-support, independent evaluation and design-review tools will be needed. The relative simplicity of evaluation - and review applications (compared to more complex design tools) provides another advantage: reaching the goals (in terms of IT development and deployment in practice) relatively easily, they constitute a sort of incubator ecosystem - that, as it happens not rarely, can breed more complex products eventually.

Nonetheless, given the issue of (lack of) interpretability (addressed in (II)) and the state-of-the-art of the field, it is not AI that may have the last say. An ongoing *advice whispering* that leads the designer to a benchmark - and sometimes "hallucinates" him based

on the training guidance in the saliency heat map - is one thing, and another is the final inspection that establishes liability.

In the long term, a tool that is an untransparent black box by its very nature can hardly secure the coveted objectivity; the question of interpretability and safety emerges again. Given the nature and gravity of their expert liability, AECO professionals appear vanguard to tackle the issue. As seen when having referred to the latest generation of structural design applications, face-to-face with the undisputable liability, not an AI algorithm that may "hallucinate" but an ordinary rule-based model that is well interpretable, is entitled to hold the control. This does not exclude machine learning from the design of bearing structures - as well as of any other feature of a building or construction, and of any design process in general - but the performance must remain controllable and controlled ultimately. Control shows to be the keyword. So far at least, no one and nothing else but humans can and thus must be liable; so, human control is it.

Keeping this keyword in mind, humanity can and will overcome the threats of AI getting independent and ungovernable. It is about understanding and tackling AI as a sort of sixth sense or a booster to the human brain - just tools, such as a saw, car, or firearm, the safe use of which requires not only responsibility but also basic skills (and sometimes authorizations) acquired through training and practicing, and, even more importantly, that man can - and must - turn off and put away whenever he is not sure that he gets what he truly wants. Eventually, this can be as simple as the switch or outlet already discussed. This simple is the theory: history shows that in practice, humanity will not be able to work it out the first time and right away - but eventually will. Coincidentally, given the nature and habits of the field, AECO renders the pathfinder. A car alike a medicine must not enter practical use until it has successfully undergone comprehensive testing that simulates reality in every conceivable way; not so a construction. Designed in a non-material environment, construction is implemented - materialized straightforwardly relying on there is no error in the non-material model represented by plans. Lacking the comfort of prototyping and operational testing and being aware of the responsibility society has placed upon them, AECO professionals must claim liability as their innate concern. Who would rely on a non-transparent, non-interpretable black box in such respect?

d) Specifying the Criteria of Optimization and Assessing

Being aware of an issue on time is halfway to eliminating the threat. Globally as well as within the vast majority of nations and regions´ populations, there are three most frequented topics today: politics, climate change or environmental and resources sustainability, and technologies; architecture, hence the built environment as the (by man) synthesized sphere of the world of our existence intertwines each of the three. So far, technologies are falling behind in this respect - as our experience shows when it comes to politics that adopted only the information and communication benefits of the technologies, and as this paper has clarified concerning architecture. Identified as one of, probably the decisive among the "Green Transition" factors only recently, the technologies are just on the brink of the proper deployment towards sustainability.

The state-of-the-art how those most frequent issues are approached reflects the annotated underdevelopment. Still too frequently we take in consideration the threat only when it becomes an existing problem - be it the earthquake in Turkey and Syria, soon after in Tajikistan and China, gas – and petroleum-supply shortages all over Europe and grain supplies shortages in many counties of the world as a consequence of Russia´s attack on Ukraine - leaving aside out-of-imagination damage to Ukrainian infrastructure and building stock, not talking about life losses and human and all living beings sufferings, the Fukushima tsunami, the Grenfell Tower fire, the use of cancer-causing asbestos fibers in construction, or the development of harmful fungi in the internal environment of buildings as a result of their insufficient thermal insulation and ventilation.

And even worse events can attack the global civilization: events escaping our attention consistently despite conclusive and evidenced experience. Erupted in 1812, the Tambora volcano caused a three-year global „solar eclipse“ and a catastrophic famine that struck the entire planet [111]. What would be the consequences of a geophysical event of similar magnitude today? The average temperature during the next decade would plummet at least 1.5ºC lower; so far not bad - but much worse to come. Areas and populations dependent on agricultural production would suffer probably the same as two hundred years ago. Another period of sustained extreme weather would begin. Extreme rainfalls would intersperse with long periods of extreme drought. To be alive during the three years after the eruption would be to be hungry: crops would freeze before there would be anything to harvest or would be washed away by downpours and floods. Where would economically advanced countries import food from? Would they remain economically advanced if consumers and governments would lose interest in any products that would not very directly address the basic needs of life? What about energy supplies? Solar power would cease to exist; wind power would be available more rarely - in the brief interludes between hurricanes and no wind. Anyone would take credit for „good old“ fossil and nuclear fuels - as long as the transmission grids, sorely tested by extreme winds, would work, of course. Nor would shipping be relied upon due to

extremely rough seas, and the resilience of oil and gas pipeline structures to flooding and landslides would be demonstrated.

A disaster like the Tambora one will most likely happen again - just as such disasters would happen before it. How are we prepared for it? Are we counting on it at all?

Also, catastrophic events like the tsunami that damaged Fukushima nuclear power plant can happen again today and in the future [111]. The 8.9 magnitude earthquake with its epicenter in the sea to the east of the Japanese island of Honshu is not pre-history. The tsunami that it triggered caused nearly 16,000 deaths and $300 billion in damage to Japan's economy. The Fukushima power plant explosion caused over 200,000 people evacuated from the vicinity of the plant and nearly 6 million households left without electricity for days or weeks. After the Fukushima accident, Germany decided to shut down all its nuclear power plants and not build new ones. Situated on a very stable Eurasian tectonic Plate, Germany took this decision as an act of support for renewable energy sources. However, were other contexts considered responsibly and rationally? Today, German nuclear power plants are shut down and their performance does not replace - unless the wind blows or the sun shines intensely enough - the somehow acceptable steam-gas generators because they would have to burn politically unacceptable gas from Russia, but the coal-fired power plants: the proclaimed Environmental, Social, and Governance goals sidelined, CO2 emissions are increasing instead of decreasing.

The world is interconnected and interwoven at all levels and in between, be it the energy efficiency of a particular building, sustainability of local ecosystems, or resilience of the global synthetic living environment. We are beginning to understand this and are only on the brink of a suitable comprehensive approach; we stand here empty-handed. We are still half empty-handed concerning even the particular, not-so-comprehensive tasks we have accepted; energy efficiency and a complex environmental footprint assessment of a particular development project can perhaps be an example of at least partially overcoming the lagging [112]. A comprehensive resilience of our ecosystem - yes, even if we would be selfish and would have forgotten the rest of the planet - that encompasses, if not starts with our built environment, is an issue that waits behind the horizon of both today´s perspective and know-how - no matter whether it comes to living conditions of humanity as a whole, to a city district or a neighborhood, or a building. However, all these issues have today a not-so-complicated-to-find track in the data available to experts, if not open-access data. And here we go: who else but AI shall make such research, and what else could be easier for AI to find? Moreover, deriving continuation from the existing sequence, it is predicting the future from the history is business as usual for AI. So, no reason (and no time) to wait, shall the development of respective models and algorithms launch! The material and life- and health-saving benefits are obvious and easy to calculate; even without calculating, the development in this field will pay off.

e) Changing the Game

A reminder of the lagging of architecture, the development of the built environment, and real estate behind global societal and economic development opened this paper. Previous chapters and paragraphs reveal the potential of feasible deployment of AI in these fields: an immense potential of various but interconnected ways of deployment that not only contrasts with the so far wavering approach to the new technology but can provide essential contributions to responding to diverse existing social, cultural and economic, and environmental challenges.

The pipedream of truly creative AI debunked as an unrealistic chimera, the more the next efforts can concentrate on parametric issues and pattern-based generative (co)design. As a small but not meaningless contribution to the understanding revisited, the so far misuse of the term "Artificial Intelligence" should be avoided. What we have so far, what is ready to work, and what is capable to cope with all the challenges in the field of architecture, construction, and all the other expertises involved design and planning, is machine learning (ML) - nothing more and nothing less; and that´s enough for the task too.

The first to change is the paradigm of designing architecture and the built environment, and the whole AECO. Once the ML tools - algorithms, models, platforms - as outlined in previous chapters apply appropriately and as intensely as it deserves in the parametric realm of architecture and development of the built environment, the process of designing becomes not only significantly more efficient and productive and less time- and cost-consuming, but (a sort of) consequential and objective, too - which does not mean a loss of creativity. The impacts on a comprehensive quality of architecture and the built environment show obvious, notable, and positive. A shift in sense of the quality of the service and deliverables within the architecture - and relevant other designers´ professions renders a clear perspective of an optimization of the outputs that probably will overcome essentially not only today´s practice but any expectation, too. Though repeatedly, the contribution also for poetic creativity that is essential for authentic architecture deserves and needs remark at this point: not a direct contribution but a subsidy through creative energy, attention, and capacities released by the deployment of ML´s mimetic capabilities in the parametric realm: a release of the potential and capacities of human creativity in place

of the misconceived fruitless trying to learn the machines to be truly creative.

Another benefit of ML´s deployment in the AECO field is the growth in the objectivity of evaluation and review of the solutions. Opposed to the so far, particular-experience-and-knowledge-dependant, and, as human, inevitably mistakes-making practice in this field, ML can provide a close-to-objective assessment related to (close-to) objectively complete criteria set. Respecting the dual nature of architecture, comprising both poetic aspects and parametric and physical properties and performance, ML can enter the design and planning processes as well as optimization, reviewing, and evaluation of the designs more intensely, deeply, and systematically. If it can, for the sake of the economy, quality of individual and social life, culture, sustainability, and comprehensive resilience it should. The operational fields are generative parametric, pattern-based (pre)design (as drafted in (IV)), *assisting the human designer* in adapting the pre-designs, and tailoring the final, specific solution.

It is not so challenging to figure out that a suitable and comprehensive training dataset will allow for the birth of both the list of parameters to review and the methods to quantify the particular values to make comparable the complex performance of a building or an entity of the built environment - the performance represented by values of definite parameters. The training datasets are just compositions of our knowledge of the existing building stock, the built environment, and the properties and performances of particular constructions and construction materials and products; nothing special, no nuclear physics, nothing inaccessible or unmanageable - except for the amount of data and the complexity of their structure:-). Understanding ML on the level of this paper gives comprehension that such an assessment is achievable not only when all data to be taken into account are provided: Adequately trained, ML can evaluate every parameter and the complex at any level of design development, from any sketch or specification, and based on this, ML can *advice whisper* (as coined in (IV)) how to develop the design further or what to avoid. A prerequisite for this shows that ML-driven design development and planning becomes a compulsory standard that wil bring every design to the state-of-the-art level of development in terms of the comprehensive quality structure.

Automation-aided design and optimization together with assessment of the objectivized parametric results achieved thus may seem to create a systematic circular reference. However, it is not so. Human intervention will remain critical: In the first phase, the human approach to the compilation of training datasets and supervised and reinforced learning (among others) will be decisive. And always, creative feedback concerning optimization criteria and interim outputs of the GANs, VAEs, streamlined Generative AI, or other, today not yet existing types of ML networks´ processes will be appreciated. Already the decision of particular tools deployment for a specific task will remain a kind of creative input, though of a so far not experienced nature. Most probably, it will not be a performance of new specialty expertise - of a "superuser" [96] combining superb architectural, mathematic, and IT background - already due to scarcity of such brilliant minds - but a close and balanced cooperation of "good old" architects ingenuously teamed up with IT developers, designers, and operators.

The perspective is realistic; it is not a task for the distant future - the implementation can start now and the MVPs (minimum viable products) can be there in les than half a decade. The motivation is the economy in terms of the efficiency of development of the built environment, a business opportunity in terms of filling a market niche, comprehensive quality of our lives, and our sustainable future - also in terms of comprehensive resilience. It may be just about how to make these goals as motivating as the financial profit that motivates the R&D of Google or Microsoft. DeepL (by DeepL SE) and Google Translate do not only translate but *whisper* how the text might go on - similarly to how this paper sketches ML architecture design tools to work.

f) Prospects for the Architectural Profession

Last (in this paper) but not least, the technology of ML reveals prospects for the architectural profession. Not only the contributions of ML deployment in architecture and the whole AECO in terms of increasing the quality of designs and planning processes, the efficiency, and productivity of designers´ and planners´ work, and reducing its time- and cost-consumption appear on the horizon. By bringing objectivity and consequentiality into the design and planning processes, ML can perhaps contribute to the coveted transformation of the medieval-guild craft of architecture into the industrialized profession that is up to the social, cultural, and economic state-of-the-art of the 21st century, also in terms of social and economic conditions of exercising the profession [113].

Imagine an objective and comparable assessment of any aspect of a building or an enclave of the built environment that can be parametrized or, other said, of the material side of the future building or the future enclave of the built environment is achievable. What then remains unassessed quantitatively and hard, if at all, to compare, is the poetic side of architecture - of a building or an enclave of the built environment, unassessable by ML, by any algorithm, and starting from any training dataset. Though the *poetics [of architecture] is only then authentic when shared* [91], even then it remains hard to assess and compare objectively. Based on long-term observations of the real estate market and the assumption that in long term, a

value finally turns into the price (yes, often only in a very long term, and only indirectly, but still)- a price of a building, a rent collected, and similar - it shows that the objectively assessable, parametric performance of a materialized architecture make up big portion if not most of the total value of a building: at a guess, 90%, perhaps even more at "production", mass-production architectures, 80% or more at local and contemporary icons and landmarks (taking into consideration as detached the portion of the total value of property attributable to the plot of land, which follows the land rent or its gradient respectively). A bigger, even majority share belonging to the poetic aspect of a particular architecture´s value comes with the age of the architecture´s material substance - typically alongside the rise of the cultural, societal, and political meaning of the particular architecture, which, logically, can only exceptionally occur at a new artifact.

Given an objective quantitative and comparable assessment of a building´s or an enclave´s of the built environment value, a much more objective and comparable assessment of a design or a planning performance may eventually conclude in a more objective remuneration of the work made - remuneration of an architect that would cope with remuneration of other professions comparing in terms of quality and scope of the work and qualification needed; consider lawyers, physicians, or managers. Today, the remuneration of architects and their working conditions stay so much behind that architects have no other chance but to strike and unionize - opposed to the mentioned and many other professions that require responsibility, magister graduation, and additional proofs of qualification, not talking about creativity.[114-119] Moreover, the issue is not only remuneration of commissions: emblematized by widespread architectural competition that has close-to-nothing to do with Toynbeean industrial competition [120] and is unable to be objective in today´s technological conditions, the working and business conditions of the architectural profession cannot catch up with business-as-usual of the economy.

And second, it is not only architects who deserve better work conditions. The bad working conditions cannot but imply a worse-than-optimal performance eventually. Thus, the clients and whole society are the victims of existing conditions. As sketched in this paper, ML can contribute essentially to the remedy to the situation.

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PVSET- CIES, Graphic Interface. Quantification of the Degradation Index of Photovoltaic Systems

By Roger Anner, Proenza Yero, José Emilio, Camejo Cuán & Rubén Ramos

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The result presented, Graphic interface PVSET-CIES, contributes to the improvement of the efficiency indicators of the systems. For this, the procedure "Quantification of the degradation index of the photovoltaic grid connection systems" was developed, which allows passively evaluating the degradation of the systems, from the quantification of the degradation index.

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PVSET- CIES, Graphic Interface. Quantification of the Degradation Index of Photovoltaic Systems

Roger Anner, Proenza Yero [α], José Emilio [σ], Camejo Cuán [ρ] & Rubén Ramos [ω]

Abstract- The use of the Performance Ratio or global performance is a simple and effective method to evaluate the performance of photovoltaic grid connection systems. Nevertheless, there are theoretical reasons and experimental evidence that show that this parameter varies throughout the year by as much as 10%, which prevents any value measured over a week from being considered representative of what occurs throughout the year.

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The scientific novelty is based on the robustness of the coefficients used in the diagnosis against environmental conditions, varying about 1.5 %, unlike the Performance Ratio procedure, which varies up to 10 %, and the accuracy in terms of the model´s prediction capacity used, achieving a prediction error three times lower than the maximum power estimation model used in the Performance Ratio.

The graphical, interface PVSET-CIES, is supported in this procedure. The tool provides information on energy losses and system degradation, which serves as a prerequisite for decision makers, for the development of maintenance and/or repair programs that keep the system at optimum operating levels.

Keywords: grid connected photovoltaic systems; procedure; performance ratio; graphic interface.

I. Introduction

The Program for the Development of Photovoltaic Solar Energy in Cuba, executed by the National Electric Union, as of 2013 covered the construction and commissioning of Photovoltaic Parks (PPv) located throughout the country, maintaining a growing trend in its introduction in the country. Thishas allowed more than 72 PPVs to be installed with a total power of 215 MWp out of a planned power of 700 MWp for 2030.

One of these is the PPv, "Santiago — CIES", located in the Abel Santamaría , Micro 3, Santiago de Cuba Municipality, province of the same name, in the part of the land occupied by the Solar Energy Research Center (CIES), at the following coordinates, Latitude: 20° 00′ 75″ and Longitude: 75° 77′ 07″.

The "Santiago – CIES" Photovoltaic Park of 2.5 MWp, is made up of two photovoltaic generators (GPv), made up entirely of 10,400 photovoltaic modules (MPv) of 250 Wp power (model DSM-250-C) assembled in Cuba, grouped into 520 work tables, conveniently interconnected to 130 three-phase grid connection inverters (ICR) (model SB 17000TL), manufactured by SMA, with a nominal power of 17 kW each. The PPv contributes its energy to the local electrical network at a nominal voltage level of 13.8 kV, through two three-phase coupling transformers.

In 2016, CIES carried out a project linked to the national program of Renewable Energy Sources, entitled: Evaluation of the Photovoltaic Park Santiago - CIES of 2.5 MWp connected to the National Electric Union, whose main objective was to know the performance in operation of it, since, since its implementation, the technology had not been evaluated. *The completion of it yielded the following results:*

1. There is a GPv power deviation of 7.57%, lower than the nominal value declared by the manufacturer, which indicates that, due to the nominal power deviation in the GPv, the system stops producing
2. As for the ICRs, a total of 8 failures (replacement) were reported in 2016 with a delay time of approximately 6 days, which represents a loss of 3.88 MWh, which is equivalent to USD 1,044.00.
3. It is estimated that in 2016 the Santiago — CIES, PPv operated at 91% of its nominal performance, therefore, the operational losses of the system in general amount to 25.2 MWh each month.

Like all technologies, grid connection photovoltaic systems are usually supervised according to standards established in each region and measurements can be analyzed annually. These indicators are calculated from data throughout the year to take into account the effect of seasonal variation. Due to the different levels of solar irradiance and ambient temperature, photovoltaic systems operate better at certain times of the year. The annual results can be

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compared with reference values to evaluate the performance of the system.

The use of the PR (performance ratio) or overall performance is a parameter derived from the efficiency of the system and is the most common method of evaluating the performance of the photovoltaic system, it is widely used as an indicator of quality of photovoltaic systems since, in 1993, and it was included in the IEC 61724 standard. This parameter is defined as the relationship between the energy that a photovoltaic system delivers to the grid and that which a hypothetical ideal system would deliver, understood as one whose solar cells always work at the reference temperature (25 °C) and that, therefore, otherwise, it was free of losses[1]. However, there are theoretical reasons and experimental evidence that show that this parameter varies throughout the year by as much as 10%, which prevents any value measured over a week from being considered representative of what happens throughout the year.

Based on what has been stated, it is concluded that there is limited information about the performance of Grid Connection Photovoltaic Systems (SPvCG) in Cuba. For this reason, it was proposed to develop the Operational Loss Quantification Procedure (SPvCG Degradation Index), based on the relationship between the expected power and the real power for different temperature and solar irradiance conditions, supported by a measurement tool calculation, graphical interface PVSET-CIES, for the evaluation and processing of the data, with which the efficiency of the SPvCG can be substantially improved, all of this, support the need to improve the system indicators and reduce losses by taking advantage of the existing technology.

II. Materials and Methods

1. Study of the state of the art. Generalities of photovoltaic systems: evaluation and mathematical models.
2. Procedure for the quantification of the operational losses of the SPvCG.
3. Implementation and validation of the procedure for the quantification of operational losses in the CIES 7.5 kWp PV microsystem, through statistical parameters.
4. PVSET-CIES Software. Generalities

III. Results

a) Study of the state of the art. Generalities of photovoltaic systems: evaluation and mathematical models.

Overall Performance or PR considers the expected efficiency of the system under ideal operating conditions. This is a parameter derived from the efficiency of the system and is the most common method of evaluating the performance of SPVs (1).

The PR has been widely used as a quality indicator for photovoltaic systems since it was included in the IEC 61724 standard in 1993. This parameter is defined as the relationship between the energy that a photovoltaic system delivers to the grid and that which a hypothetical ideal system would deliver, understood as one whose solar cells always work at the reference temperature (25oC) and that, for the rest, was loss free.

The main advantage of the PR is that it is easy to obtain: all you need is the network's energy meter and an incident solar radiation sensor. Its main drawback is that it does not allow differentiation between thermal losses (due to the fact that the cells normally operate at temperatures above 25oC, which are unavoidable and unrelated to the design and operation of the system), from the rest of the losses, which do depend on it, it is that is, it does not distinguish between extrinsic (thermal) and intrinsic (the rest) losses.

For this reason, the so-called PR25 has recently been used, defined as the ratio between the energy actually produced by an SPv and that which would be produced by another hypothetical one with the same nominal power, which would not be affected by any type of loss and whose cells would operate at the same temperature as that of the real system (instead of 25 oC), as shown in equation 1.

$$PR_{25} = \frac{E_{AC,REAL} \cdot S^*}{P^*_{RG} \Delta t \sum_i S_i \left[1 + \gamma (T_{C,i} - T^*_C)\right]} \quad (1)$$

where:

S* irradiance (STC =1000 W/m^2)

T^*_C =25 °C

P^*_{RG} generator rated power. Δt sampling time.

I: number of measurements.

γ: coefficient of variation of power with temperature, negative value, indicated by the manufacturer.

* Standard measurement conditions SCT

b) Limitations

The use of the PR is a simple and effective method to evaluate the performance of photovoltaic systems. However, there are theoretical reasons and experimental evidence that show that this parameter varies throughout the year by as much as 10%. This prevents any value measured throughout a week from being considered representative of what occurs throughout the year.

On the other hand, PR_{25} (which considers the influence of the photovoltaic cell operating temperature), presents difficulties in estimating the maximum output

power of the GPv, evidence of this is presented in [2], where the error The absolute result of the analysis of one day between the actual measured and the estimated power is 3 times greater than that estimated from the five-parametermathematical model, [3].

IV. Mathematical Models of the Photovoltaic Generator and Grid Connection Inverter

a) Mathematical model of the GPv

There are several models to predict the energy production of a MPv, a string, or an array under certain conditions, most of these are based on current-voltage (I-V) relationships that result from simplifications applied to the diode model double[4]:

- Model of 5 parameters.
- Model of three parameters.
- Sandia Array Performance Model (SAPM).
- King's model.
- Luft's equation and others.
- Hadj Arab equations and others.

For this research, the modified relationship was resolved using the 5-parameter model, popularized by [3] since, unlike the other models, it only requires information provided by the manufacturers and its concordance with experimental results has been demonstrated.

b) ICR mathematical model

For the ICR, a model that simulates its efficiency based on two resistors is presented below: one in series with the input and another in parallel with the output. Between the two there will be an ideal investor, understood as the one in which there is no loss. This is a model with physical meaning[5], as opposed to other purely mathematical models[6]. It has the advantage of simplicity over other models based on the topology of the electronic circuits constituting the inverters that have been presented by [7, 8, 9] or on its behavior [10].

The equation that defines the behavior of the inverter efficiency is the following:

$$\eta = \frac{2R_s P_{ac}}{V_{dc}^{\ 2}\left[1-\sqrt{1-4\frac{R_s}{V_{dc}^{\ 2}}\left[\frac{V_{ac}^{\ 2}}{R_p}+P_{ac}\right]}\right]} \quad (2)$$

c) Procedure for the quantification of the operational losses of the SPvCG

The energy losses that occur in a photovoltaic system, operational losses, are inherent in any photovoltaic system; they are associated with the inconsistency between the nominal efficiency declared by the manufacturer and the real one, the resistive energy losses in the cables or the losses due to component degradation. The actions aimed at minimizing operational losses aim to maintain the nominal operating conditions and ensure the warranty terms of the main elements that make up the system.

For this, the option that is exposed starts from considering that the behavior of the photovoltaic generator is calculated from the 5-parameter model [3], the input variables are: the incident irradiation (S) and the operating temperature of the cells solar (Tc), figure 1.

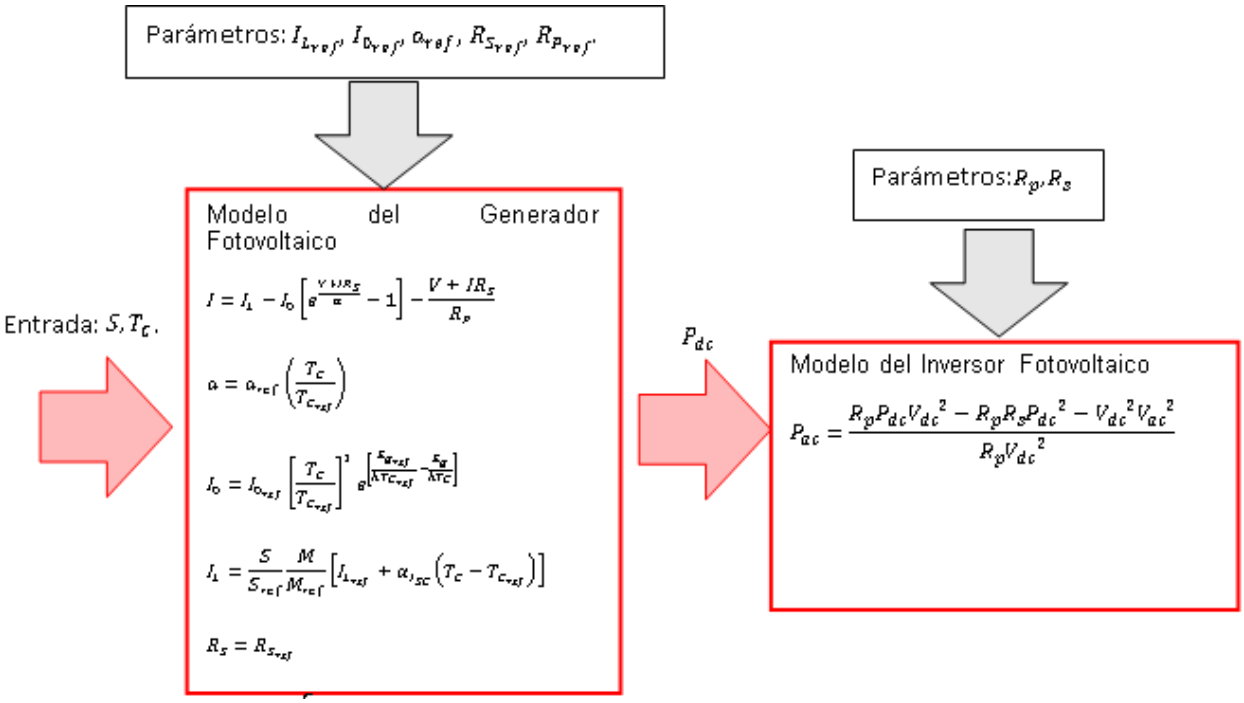

Figure 1: System of equations that define the behavior of the SPvCG

The procedure to quantify operational losses Consists of:

From a SPvCG Operation Database:

- Obtain the power, voltage and output current of the photovoltaic generator for the irradiation conditions (S) and temperature of the PV module (Tc) for a sufficient time to cover most of the spectrum of operating conditions [1].
- Calculate the power, voltage and output current of the GPv starting from the model described above, for the irradiation and temperature conditions of the Pv module obtained from the SPvCG operation database.
- Compare the power, voltage and current of the Operation Database with respect to those obtained from the model, and perform a polynomial adjustment for these variables.

The structure of the polynomials is definedbelow:

$P_{dc,EXP} = (a_{Pdc} + b_{Pdc}(T_C - 25°C) + c_{Pdc}S)P_{dc,SIM}$; a_{Pdc} defined by the line $P_{dc,EXP} = (a_{Pdc})P_{dc,SIM}$

$V_{dc,EXP} = (a_{Vdc} + b_{Vdc}(T_C - 25°C))V_{dc,SIM}$; a_{Vdc} defined by the line $V_{dc,EXP} = (a_{Vdc})V_{dc,SIM}$

$I_{dc,EXP} = (a_{Idc} + b_{Idc}(T_C - 25°C))I_{dc,SIM}$; a_{Idc} defined by the line $I_{dc,EXP} = (a_{Idc})I_{dc,SIM}$

where:

S, is Irradiance, expressed in $\frac{W}{m^2}$.

is the operating temperature of the Pv module, expressed in [°C].

$P_{dc,EXP}$, $P_{dc,SIM}$ is the output power of the GPv measured and simulated respectively, expressed in [W].

$V_{dc,EXP}$, $V_{dc,SIM}$ is the output voltage of the GPv measured and simulated respectively, expressed in [V].

$I_{dc,EXP}$, $I_{dc,SIM}$ is the output current of the GPv measured and simulated respectively, expressed in [A].

d) Analysis of data. Evaluation criteria

The evaluation process in the GPv is carried out using the 5 Parameter Model. Initially, the parameters for the standard measurement conditions are estimated and the maximum power at the GPv output is obtained, as well as the voltage and current at the point of maximum power, estimated for each of the pairs Irradiation and Operating temperature that make up the measurement table.

The maximum measured power is taken as a reference value for the polynomial adjustment of the surface formed by the simulated maximum power, based on (Irradiation and operating temperature). In the case of voltage, they are taken as pairs of coordinates (Vdc,sim, Vdc,exp) for which a curve fit is made, the same happens for current (Idc,sim, Idc, exp).

Through these adjustments it is possible to determine the degradation of the GPv according to the coefficients a, b and c, where a is the main deviation coefficient. It is calculated as follows, d (%) = (1-a) *100%.

At this point, the degradation index obtained is compared with that corresponding to the system, taking into account the years of operation of the GPv. If the degradation is within the interval declared by the manufacturer, Datasheet, the current state of the GPv is taken as positive, if the estimated degradation exceeds the interval it is taken as negative and if it is lower, the system performance is taken as positive.

e) Implementation and validation of the procedure for the quantification of operational losses in the SPvCG 7.5 kWp PV microsystem, through statistical parameters

For the validation of the procedure for the calculation of the degradation index, it was necessary to carry out field measurements with the curve tracer. 8 PV modules and the chain formed by these modules, which have an operating time of 9 years, were evaluated.

f) Experiment Design for Field Measurements

First, the I-V 400 curve tracer was parameterized to evaluate modules manufactured by HELLIENE model 215 MA based on the information provided by the manufacturer's Datasheet. The instrument was connected to the module and measurements were obtained every 15 minutes, for two days, sufficient to cover the greatest number of operating conditions, taking as a premise what is referred to in the IEC 60891 standard. Then the chain formed by the eight modules used previously was evaluated for three days.

Field measurements with IV 400 curve tracer

The measurements were made with an I-V Curve tracer, brand HT, model I-V 400 manufactured by HT Instruments, complying with the standards of the IEC 60891 standard. This instrument directly allows obtaining the I- V curve and the characteristics of the main electrical parameters of the PV modules, up to a maximum of 1000 V and 10 A, with an accuracy of ± 2%.

210 I-V curve measurements were made to the PV modules, with the environmental variables in this range: Irradiance [565$\frac{W}{m^2}$; 1146 $\frac{W}{m^2}$] and operating temperature [41.3 °C; 59.7°C]. Table 1 shows the information provided by the instrument, the result of 10 of the measurements made. The measurements went through a filtering process before being used for the validation of the method, based on what is referred to in the IEC 60891 standard.

Table 1: Actual Measurements with the I-V Curve Tracer

Measurements	Pmax (Wp)	Voc (V)	Vmpp (V)	Impp (A)	Isc (A)	Irradiance ($\frac{W}{m^2}$)	Operating temperature (°C)
1	155.01	34.43	26.79	5.79	6.38	792	45.2
2	155.36	34.36	26.79	5.8	6.42	793	45.5
3	155.43	34.25	26.72	5.82	6.47	797	46.1
4	160.26	34.06	26.65	6.01	6.73	828	47.6
5	160.9	34.15	26.65	6.04	6.75	832	47.5
6	161.14	34.07	26.65	6.05	6.75	834	47.2
7	160.34	34.06	26.65	6.02	6.73	829	47.5
8	166.45	34.22	26.36	6.31	6.95	857	46.3
9	166.08	34.22	26.29	6.32	6.98	860	46.9
10	168.92	34.15	26.79	6.31	7.11	874	48.5

The measurement of the incident irradiance was carried out with a model HT 304 reference cell, of the same technology and material as the photovoltaic module, placed coplanar to the module and the measurement of the cell temperature, using a PT300N model resistance thermometer placed in the center of the back of the photovoltaic module. It should be noted that, in order to select the area where the resistance thermometer was placed, an inspection was previously carried out with a Thermographic Camera (FLUKE) to avoid false measurements of hot spots, discarding these candidates.

The Statistical Parameters used to Validate the Procedure Were:

- Coefficient of determination of the line is nothing more than the percentage of variation of the response that is explained by the model, that is, how well the result of the procedure fits the real measurements, this parameter varies from 0% to 100 %. The higher the value of the coefficient, the better the method will fit the data.
- Root Mean Square Error (RMSE) provides a measure of error in the same units as the variable under consideration.
- The percentage of the root mean square of the error (RMSPE), where the error is normalized with the use of the averageof the measurements.
- The mean absolute error percentage (MAPE) gives a weighted measure of the previous parameter with respect to the actual measurements.

Starting from the 210 measurements obtained in the field as part of the tests carried out, the aforementioned statistical coefficients were calculated. It is essential to keep in mind that 8 PV modules and the chain formed by them were evaluated. Several measurements were obtained from each PV module, which were, averaged to obtain their degradation.

The fundamental objective of the procedure is to calculate the maximum power deviation of the photovoltaic generator between the power declared by the manufacturer and the real one, for the validation the deviation resulting from the procedure and that thrown by the curve tracer were related, as shown in the figure 2.

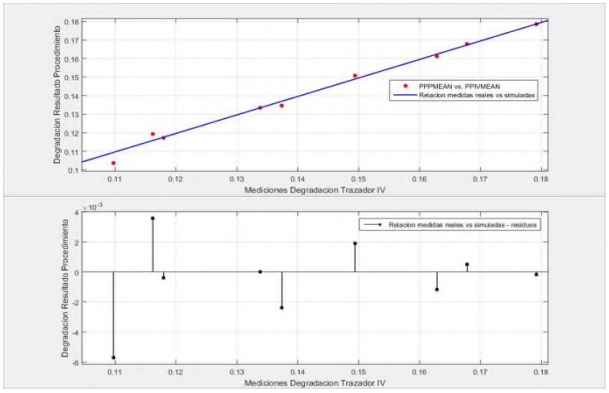

Figure 2: Relationship Between The DegradationResulting From The Procedure And Tracer I-V 400

In figure 2 it is possible to appreciate the relationship between the variables analyzed, a polynomial adjustment of the type $ax + b$ which resulted $a = 0.996$ y, $b = 0.001$ direct proportionality and of equal magnitude. Table 2 shows the values obtained, the results of the analysis and processing of the data.

Table 2: Results of the Statistical Indices for the validation of the Procedure

Statisticalindices	Validation result Procedure
R^2	0.9896
RMSE	0.0021
RMSPE	1.4975
MAE	0.0017
MAPE	1.1498

The results obtained from the validation of the procedure corroborate its accuracy, achieving a determination coefficient of **0.9896**, which tells us that approximately 99% of the data can be explained by the fit line between these variables. Another precision indicator of the procedure is denoted by the calculated errors, RMSPE= **1.498%** and MAPE=**1.15%**. Due to the aforementioned, we can affirm that the procedure performs well when calculating the deviation of the

V. Generalities

The PVSET-CIES graphic interface has the following stages, which are described below:

Simulation section

Based on mathematical models of the GPv and ICR, it is in charge of simulating their behavior for different environmental conditions, figure 3

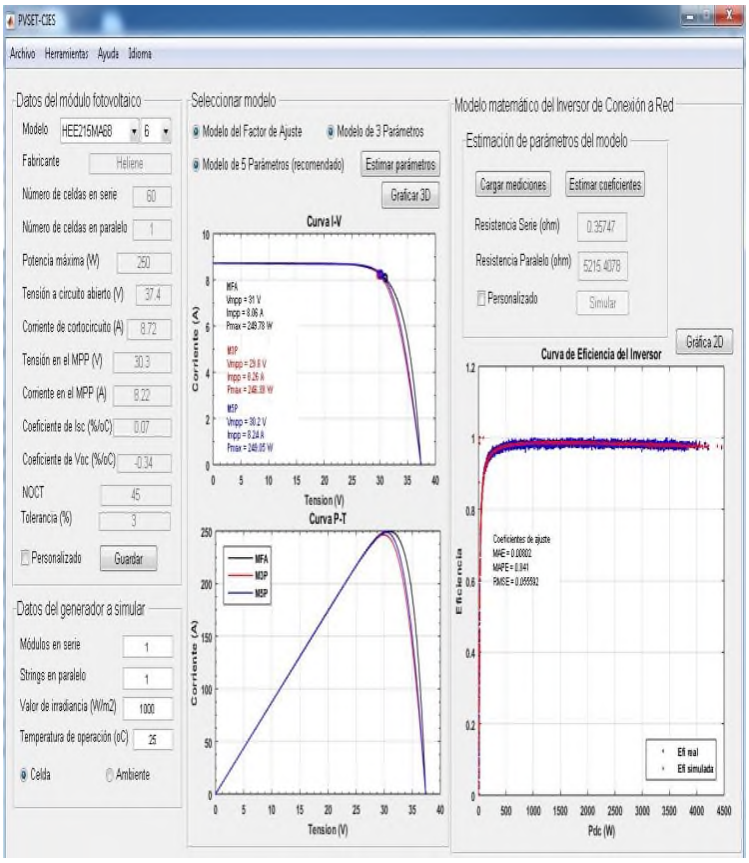

Figure 3: Simulation Window, PVSET-CIESGraphic Interface

The simulation section is formed by a simulation subsection of the photovoltaic generator, where the *data of the photovoltaic module* is loaded, in which the user can select the photovoltaic module (MPv) that makes up the generator to be simulated from a database that it is loaded automatically when the application starts, for which said database must be in the execution directory with the name "BDM.xls". In case the BDM file is not found or is invalid, the application displays an information box and creates a new empty database file (without MPv data) with the same name and structure. In the same way, if the MPv to be used is not present in said database, the user can enter the data manually by selecting the "Custom" option and save them as a new MPv by clicking the "Save" button. In the lower right part, the configuration of the GPv to be simulated with the corresponding environmental values is determined.

The middle section corresponds to the selection of the type of mathematical model to be used for the simulation of the GPv, in it there are three models, but as we already explained, the recommended model, with greater precision, is the one with 5 parameters. The output graphs are I-V and P-V, in which the maximum power point is located for the simulation environmental conditions.

Finally, the section on the right corresponds to the simulation of the Grid Connection Inverter. In which the user can establish the coefficients that define the mathematical model that simulates the inverter, or estimate them from a database of inverter operation. Said database must be in the execution directory with the name "BDI.xls".

Evaluation section

Based on the data supplied in the simulation section (MPv and ICR parameters), it is responsible for evaluating their behavior for different operating conditions, obtained from the database, see figure 4.

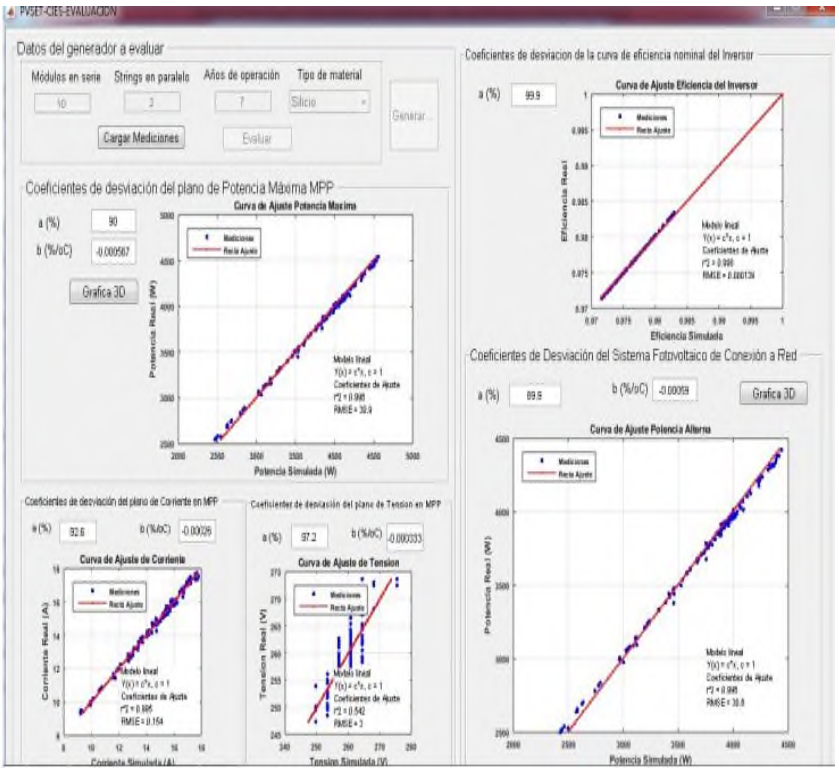

Figure 4: Evaluation Window, PVSET-CIESGraphic Interface

The evaluation window is in charge of showing the results obtained, as part of the implementation of the procedure for the quantification of operational losses in photovoltaic systems. It must be specified that, in the visualization field of the results of the power evaluation, the graphs on the left correspond to the evaluation of the GPv and the graphs on the right, upper, evaluation of theICR and lower, to the SPvCG, respectively.

Graphic 3D

In the simulation section, the tool allows, based on the electrical characteristics of the MPv, to build the theoretical maximum power plane for the nominal conditions described by the manufacturer. In the evaluation section, the tool allows to build the real power plane for degraded conditions. Simulations can be performed for different ranges of irradiance and operating temperature, figure 5.

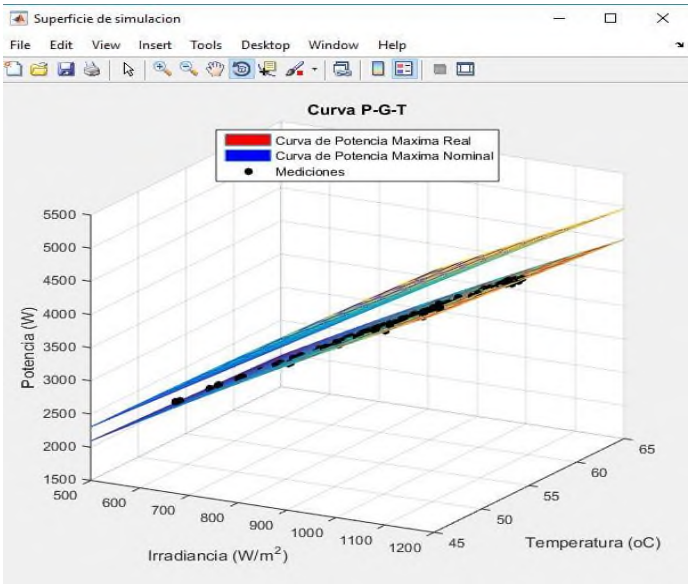

Figure 5: Maximum Power Plan for Nominal AndDegraded Conditions

VI. Conclusions

The precise quantification of the operational losses in a SPvCG allows characterizing its operation and taking maintenance actions if required. This indicator, unlike the PR, does not depend on environmental conditions and is more rigorous in terms of calculating the power estimated by the model.

The results obtained from the evaluation of the GPv and ICR models corroborate their accuracy, achieving a correlation index greater than 0.98 in all cases. The fundamental disadvantage of the GPv model lies in the solution of the mathematical equations that define the system, but, with the computing resources and processing capacity available, the simulations are efficient and fast.

The validation of the procedure through statistical parameters corroborates its accuracy, achieving a coefficient of determination of 0.9896, as well as RMSPE=1.498% and MAPE=1.15%.

The Graphical Interface, PVSET-CIES, was developed, which allows the evaluation of the SPvCG in an interactive and easy way for the user. The tool provides information on energy losses and system degradation, which serves as a prerequisite for decision makers to develop maintenance and/or repair programs that keep the SPvCG at optimum operating levels.

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Stocastic Modelling of Scaling Index, Fracturing and Parameters Performance of Produced Water Re-Injection in a Hydrocarbon Acquifer Field

By Kingsley E. Abhulimen, Fashanu T. A. & Odiachi J. C.
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I. Introduction

Produced water Re-injection (PWRI) into spent hydrocarbon aquifer offers economic and environmental friendly way to maximize disposal of produced water into the offshore and deep offshore field environments *[1].* However gradual shut down of aquifers due to injectivity decline, formation damage, cake formation and fracturing of the internal walls of the aquifer limits its use as a sustainable water resource for secondary oil recovery production *[2].* Maintaining injectivity requires minimizing formation damage near injection wells [3, 4, 5]. Recent studies by *[Ibidapo Obe et.al 2016] [6] and [Abhulimen et.al. 2018] [7]* demonstrated the significance of Internal filtration, Geochemical reaction-scaling, adsorption of particles to surface grain, hydrodynamic molecular transport in formation damage (permeability decline),and an injector decline performance. Their work however only covered numerical methods to solve the resulting physical models and did not cover assessments realized stochastically to predict performance of injection produced water, formation damage progress and scaling index, which is the objective of this study. Reinjection offers solutions to management of produced water reinjection and ensures compliance to stricter regulatory requirements for operators of offshore fields, their re several risks associated with its use which out weights its benefits. Numerical prediction of formation damage, fracturing, injectivity, petroleum production performance and pressure distribution for produced water re-injection in depleted reservoirs for most reservoir fields is limited because applicable data for input in the numerical deterministic model is only available for only a small number of data for spatial locations [8]. Thus problems associated with prediction of reservoir performance based on numerical approaches required prediction to be inaccurate in some instances making the case to use stochastical approaches with multiple random simulations trials implemented to estimate the uncertainty associated with stochastic probabilistic distribution of the input parameter. In recent studies, [9, 10] a methodology for modeling injectivity impairment during produced water disposal into low-permeability is reported [11, 12]. Recent approaches in history matching recognized that quantifying uncertainty requires multiple realizations of produced water reinjection performance data integration, risk assessment, quantification of uncertainty being a key issue in formation damage evaluation, reservoir characterization and development. Several models have been used to predict water reinjection [13, 14, 15, 16, and 17]. High rates of oil production are the direct result of pressure maintenance enabled by water reinjection. Early injection ensures that the reservoir pressure remains above the bubble point pressure to prevent expansion of gas.

II. Model Development

Field data obtained from an operator and approved by the regulator was used to derive and model a statistical strategy for evaluation performance of produced reinjection related to scaling index, fracturing progression and parameter performance in an oil field which is in contrast to numerical approaches

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previously reported in literature [18,19,20,21,22,23,24, 25]. The chi-square test was used to evaluate how well a set of observed data fits a corresponding expected set. The Monte Carlo Simulation robust model strategy for the prediction of fracturing and cake formation in a multi faulted reservoir faulted is expressed in a linear regression model of the form

$$y_i = \beta_1 + \beta_2 x_{2i} + \beta_3 x_{3i} + \varepsilon_i \quad (1)$$

Where y_i is the dependent variable and x_{2i}, x_{3i} are independent variables. In the Monte Carlo model, the coefficients of the model - $\beta_1, \beta_2, \beta_3$ are fixed parameters. In practice, their true values are not known and the purpose is to estimate these values. The random error term, ε makes the model a statistical one to solve and not a deterministic model. The Monte Carlo Simulation is ran based on the regression equation such that random numbers are predicted based on the probability and cumulative distribution functions of the dependent variables. For each run, the dependent variable is predicted based on the regression equation. This simulation predicts the dependent variables at multiple scenarios and inference is drawn from the results. In F-testing of regression coefficients, in the full model as the equation above the error terms assumed are normally distributed as $e_i \sim N(0, \sigma^2)$ where 0 is the mean and σ is the variance. In the reduced model, to test a null hypothesis of linear restrictions on the coefficients, the model under H_o can be expressed as a regression model (called the "reduced model") with p regressor variables – some of which may be different from the *X's* and $p+1$ regression parameters where $p < k$.

The F-test help in comparing SS_{full} and SS_{red} to test the reduced model against the full model. SS_{full},SS_{red} denote the residual sum of squares for the full model and the reduced model respectively and the corresponding degrees of freedom. In the case that a constant occurs in both the reduced and full model, $df_{fall}=n-k-1$ and $df_{red}=n-p-1$.

The rv's SS_{full} and SS_{red} - SS_{full} are independent and if H_o (the reduced model) is true, then $(SS_{red} - SS_{full}) / \sigma^2$ is chi-square distributed with degree of freedom equal to $s = df_{red} - df_{fall}$. The F test statistic, F is calculated as $F = \frac{(SSred - SSfull)/s}{SSfull\ /df\ fall} = \frac{(SSred - SSfull)/\sigma^2 s}{SSfull\ /(\sigma^2 df\ fall)}$.

It is important to note that the T-test and F-test are types of statistical test used for hypothesis testing and decides whether or not the null hypothesis is to be accepted or rejected. This hypothesis tests do not take decisions rather they assist the researcher in decision making.

Procedure for F-test.

- Two regressions were run, one for the full regression and one for the residual.
- The sum of squares is picked out from source tables.
- The degree of freedom in both cases were determined.
- The F statistic was calculated as $F = \frac{SSR/K}{SSE/(n-k-1)}$; and H_o is rejected if F is larger than the upper 1-α percentile in the $F(s, df_{fall})$ distribution (corresponding to the level of significance, α).
- Also, written as $F = \frac{MSR}{MSE}$, where $MSR = \frac{SSR}{K}$ *and* $MSE = \frac{SSE}{n-k-1}$
- MSE is "Mean Square for Residuals that is, the ratio of SSE (sum of squares residual) to the degrees of freedom, n-k-1; MSR Mean Square for Regression that is, the ratio of SSR (sum of squares regression) to the degrees of freedom, k.

The T- statistic for each independent variable is evaluated as:

$$T = \frac{Estimated\ coefficient}{Standard\ Error\ of\ the\ coefficient}$$

The T- value helps in determining if a predictor is significant. The bigger the absolute value of the T value, the more likely the predictor is significant.

a) P – Value

The P – value shows how statistically significant an independent variable is. It is the probability of obtaining a test statistic which is at least as extreme as the calculated value. Excel software was used in computing this value. Modelling involves using previously developed data to arrive at a model that can be enumerated stochastically.

III. Field Data Description Results

The field under study is located within the central part of the onshore fields of the Niger Delta. Historically the field consists of two parts (29) and Campos Basin bloc BC-4 in Gulf of Guinea. The field is divided in two parts. Based on report by Idialu, 2014 [23] and published article by Abhulimen et.al 2017 [7], and following reference (Castellini et.al 2000, Frade CPDEP report, Meyer, R.B et.al (2003)) [28,29,30].

a) Development of Water Reinjection Project

According to reference (29, 30) studied field is a multi-reservoir, faulted anticline, heavy oil accumulation at a depth ranging from approximately 2200-2600 m subsea, in Campos Basin block BC-4. Water depth within the areal extent of the field ranges from 1050-1300 m. Studied Field will be developed as an all subsea well peripheral water flood project, with all injection below the various oil water contacts. The project use vertical or deviated water injection wells and long, horizontal open-hole gravel pack production wells. Dummy Variables were used to develop this linear

regression equation. In this case, case1 the independent variables were not divided by a base value.

IV. Results and Discusssions

a) Field Data and Fractured Injection Simulation

Figure 2 shows that PWRI does result in a significant change in injectivity due to the assumed damage to the external filter cake. Figure 3 shows fracture growth will occur at the rate necessary to rate of water reinjection. A higher injection rate increases injectivity. Figure 2 shows there is little impact on injectivity. Lower permeability results in steeper fracturing. Figure 3 shows there is almost no difference in injectivity between four, 6m perforated intervals across the whole N570 vs. one, 6m interval within the lower portion of the zone.

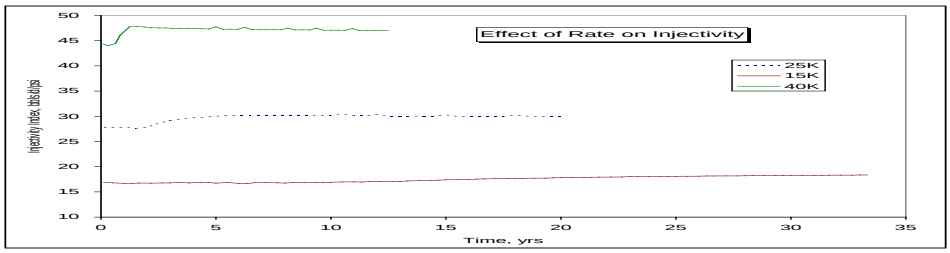


Figure 2: Effect of Rate on Injectivity

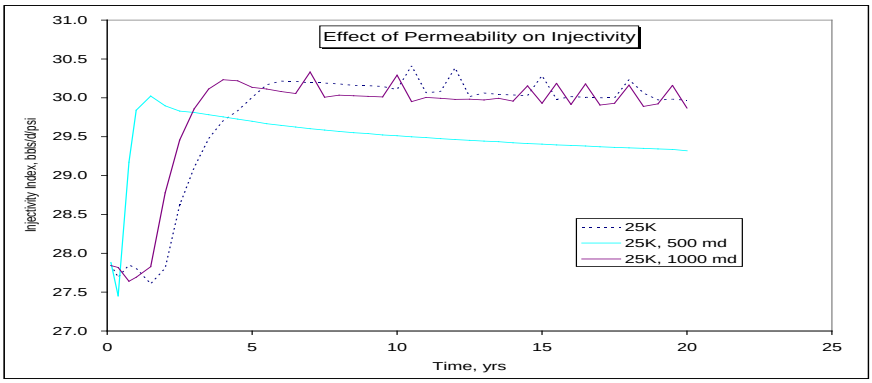


Figure 3: Effect of Permeability on Injectivity

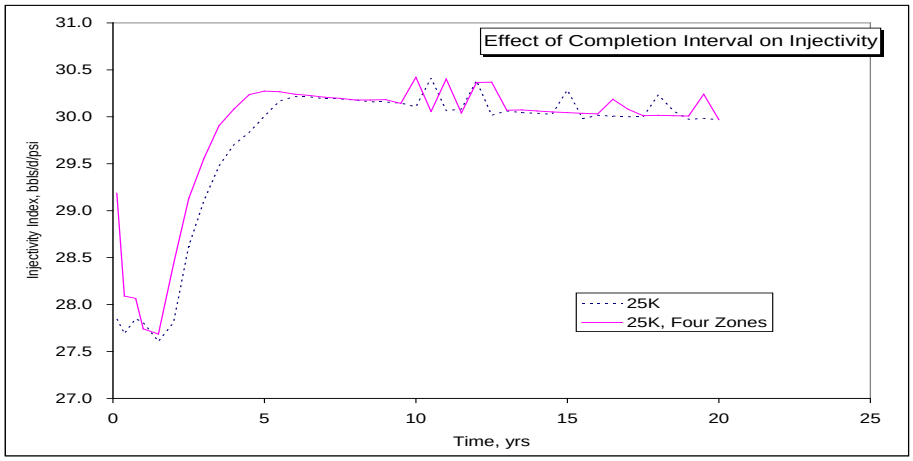


Figure 4: Effect of Completion Interval on Injectivity

In these section results of modeling analysis based on field data parameters is discussed. Table 1 is regression statistics based on data of scaling index and the other fracturing parameters were obtained from a petroleum regulator in Nigeria and as presented and reported by Idialu 2014. The MATLAB regression model Simulink provides the regression statistics results in Table 3.0. Table 4.0 is the CHI-SQUARE values of variables of Injectivity with fracturing scale production and formation damage. The regression equation is given by for scaling Index SI to predict scaling tendencies in the field studied as a function of Temperature, pressure, pH and Injection rate.

$$SI = 1 + A_1 TEMPERATURE + A_2 PRESSURE + A_3 PH\ after + A_4 pH + A_5 INJECTION\ RATE$$

Where $A_{1=}$ 0.005210855

$A_{2=}$ -9.91E-05
$A_{3=}$ 0.456150678
$A_{4=}$ -0.021847425
$A_{5=}$3.02E-07

Figure 5 shows the effect of each input on the scaling Index (output). The marker on the top right of Figure 6 show that increase the temperature from 80 to 189 make the SID increase by say 0.1 while the next marker show that increase in the pressure make the output to decrease by 0.1. Figure 5 show adjusted SI for Temperature and pH while fig 6 shows adjusted SI for temperature and pressure for any value of pH after. The SI increases as temperature increase. Figure 7 shows Adjusted SI at any temperature reading and chart indicates the SI decreases as the pressure increases. Figure 8 show interaction of the entire inputs on the output on SI and pH after. It was observed that Injection rate does not really have much effect on the scaling index.

Table 1.0: Regression Statistics

Multiple R	0.9724
R Square	0.946
Adjusted R Square	0.944
RMSE	0.00724
Error degree of Freedom	244
Observations	250

	Coefficients	Standard Error	t Stat	P-value
Intercept	-1.458805352	0.186270479	-7.83165	1.47E-13
Temp	0.005210855	0.000144843	35.97596	1.54E-99
Pressure	-9.91E-05	5.15E-06	-19.2332	8.49E-51
pH	0.456150678	0.021363995	21.35138	9.30E-58
pH after	-0.021847425	0.004520292	-4.83319	2.38E-06
Injection Rate	3.02E-07	9.03E-08	3.339175	0.000972

Table 2.0: Chi-Square Values for the Variables

	P-value
Intercept	1.47E-13
Temp	1.54E-99
Pressure	8.49E-51
pH	9.30E-58
PH after	2.38E-06
Injection Rate	0.000972

Table 3.0: T- Stat for the Variables

	T Stat
Intercept	-7.83165
Temp	35.97596
Pressure	-19.2332
pH	21.35138
pH after	-4.83319
Injection Rate	3.339175

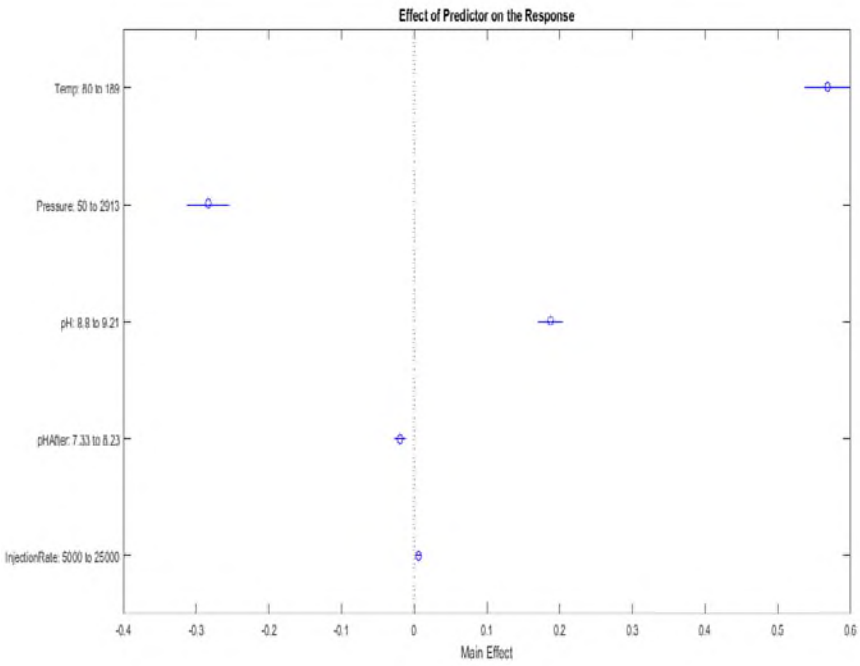


Figure 5: Effect of Predictor on Response

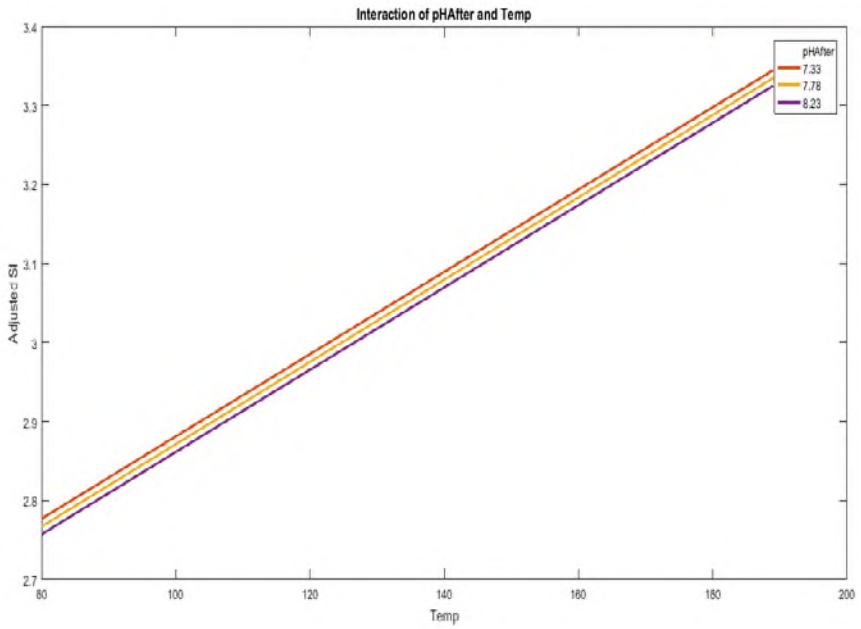


Figure 6: Adjusted SI with Temperature and pH

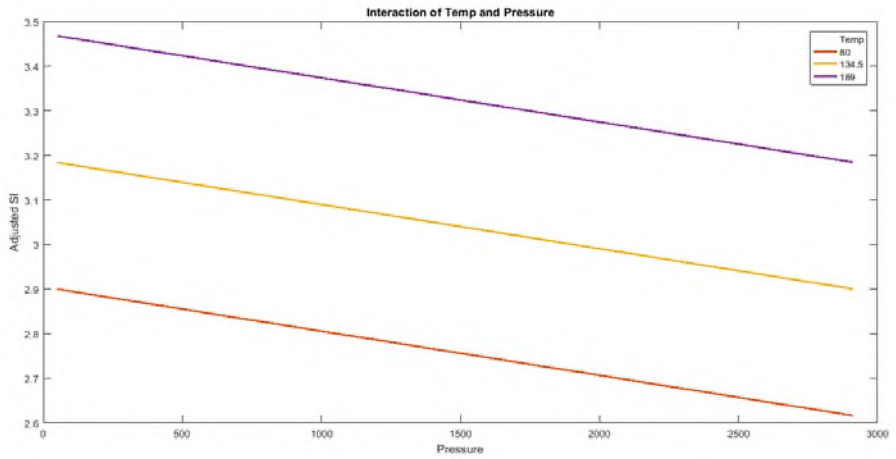


Figure 7: Adjusted SI with Pressure and Temperature

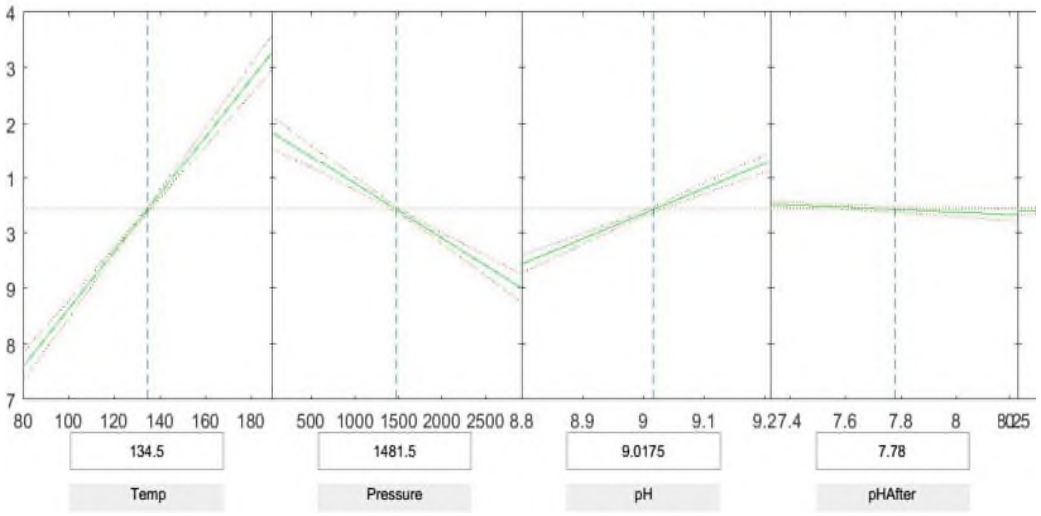


Figure 8: SI with Temperature, Pressure, pH and pH After

Table 6.0 shows the regression statistics based on field data after simulating on MATLAB to generate the regression model or equation with an R square of 97%. Table 7.0 is ANOVAs parameters. Table 8.0 shows Chi-Square test based on data on fracturing phenomenon.

Table 6.0: Regression Statistics

R Square	0.997
Adjusted R Square	0.9965
RMSE	0.00347
Observations	60

Table 7.0: Anova Paramters

	SS	DF	MS	F	Significance F
Regression	0.205440621	59	0.003482		
Residual	0.204815196	7	0.029259	2432.721	4.51E-63
Total	0.000625425	52	1.20E-05	0	

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	0	NaN	NaN
Young's modulus, psi	1.68E-10	1.36E-09	0.124152	0.901713
Poisson's Ratio	2.287796099	0.025236959	90.65261	2.48E-55
Toughness, psi-in1/2	0.00141057	0.000910887	1.548567	0.128054
Pressure, psi	-7.59E-05	0.000266942	-0.28421	0.777471
Compressibility, psi-1	-294.8436887	279.1197758	-1.05633	0.296103
Permeability, md	-9.20E-08	1.46E-06	-0.06309	0.949956
Porosity	-0.021072465	0.013422726	-1.56991	0.123006
Formation Fluid Viscosity, cp	0	0	NaN	NaN
Coeff of ThermExp (1/R)	0	0	NaN	NaN
Temp(F)	0.00567176	0.004939851	1.148164	0.256591
Biots Constant	0	0	NaN	NaN

Table 8 are chi square values for variables used to generate P values for intercept, young modulus, psi, Poisson's ratio, toughness, pressure, compressibility, porosity, formation fluid based on data provided in Appendix A Table A3

Table 8.0: Chi-Square Values for Variables

	P VALUES
Intercept	0
Young's modulus, psi	0.901713
Poisson's Ratio	2.48E-55
Toughness, psi-in1/2	0.128054
Pressure, psi	0.777471
Compressibility, psi-1	0.296103
Permeability, md	0.949956
Porosity	0.123006
Formation Fluid Viscosity, cp	0
Coeff of Therm Exp (1/R)	0
Temp(F)	0.256591
Biots Constant	0

Table 9.0: T Stat for the Variables

	T-STAT
Intercept	0
Young's modulus, psi	0.124152
Poisson's Ratio	90.65261
Toughness, psi-in1/2	1.548567
Pressure, psi	-0.28421
Compressibility, psi-1	-1.05633
Permeability, md	-0.06309
Porosity	-1.56991
Formation Fluid Viscosity, cp	0
Coeff of ThermExp (1/R)	0
Temp(F)	1.148164
Biots Constant	0

The regression equation to described fracturing phenomenon based on field data is given by

Y=1+B1YOUNG'SMODULUS+B2POISON\RATIO+B3TOUGHNESS+B4PRESSURE+B5COMPRESSIBILITY+B6PERMEABILITY+B7POROSITY+B8FORMATION FLUID VISCOSITY+B9COEFF OF THERM EXP+B10TEMP+B11BIOT'S CONSTANT.

Where Y= σ/TVD

B1=1.68E-10
B2=2.287796099
B3=0.00141057
B4=-7.59E-05
B5=-294.8436887
B6=-9.20E-08
B7=-0.021072465
B8=0
B9=0
B10=0.00567176
B11=0

Table 10: Regression Output

Residual=Output-Predicted(Fitted)

Observation	Predicted σHmin/TVD	Residuals
1	1.755176515	0.002383335
2	1.754210421	0.003282703
3	1.754196673	0.003649684
4	1.755563744	0.002167322
5	1.745017372	0.001815937
6	1.707914432	0.004508949
7	1.777649715	-0.003188842
8	1.776929853	-0.002976813
9	1.739535586	0.001000309
10	1.830843069	-0.007807289
11	1.820752739	-0.005421826
12	1.712883501	0.00694037
13	1.760415293	0.001803846
14	1.80893194	-0.000982362
15	1.806798456	-0.009183584
16	1.738907353	0.004243237
17	1.73288535	0.002451627
18	1.77603357	-0.001781725
19	1.77773054	0.000433982
20	1.788037258	-0.002962604
21	1.787112245	0.00014607
22	1.866485352	-0.001191938
23	1.898519512	-0.000441118
24	1.855876948	-0.001025834
25	1.825406668	-0.003844158

Figure 8 shows a match of predicted reservoir production rate and actual production rate and fits into trend analysis for each injectivity run and Fig 9 shows a similar trend for pressure difference is observed. The production rate is marked by peak maxima and minima for each injection run. The tables for both the production index and fracturing phenomenon simulated on MATLAB generated an appropriate model that can be used to analyses the data given. The model generated shows a good fit because the value for the Multiple R (correlation coefficient that tells us how strong the linear relationship is; value of 1 is a perfect positive

relationship while a value of 0 shows no relationship at all), R Squared (statistical measure of how close the data are to the fitted regression line)and the Adjusted R Squared (a modified version of R Squared that has been adjusted for the number of predictors in the model) tends towards 1.0 while the value for the Standard error or the Root Mean Square Error (RMSE) which measures how much error there is between two datasets, compares a predicted value and an observed or known value and the Mean Square Error that measures the average of the squares of the errors or deviation i.e difference between the estimator and what is estimated. Figure 9 shows the effect of each input on the output (Scaling Index). Increase in temperature will directly lead to an increase in the value of the Scaling Index but reverse is the case for pressure. Figure 9 also shows the interaction between all the inputs on the output. pH after and Injection rate does not really have much effect on the output (Scaling Index).

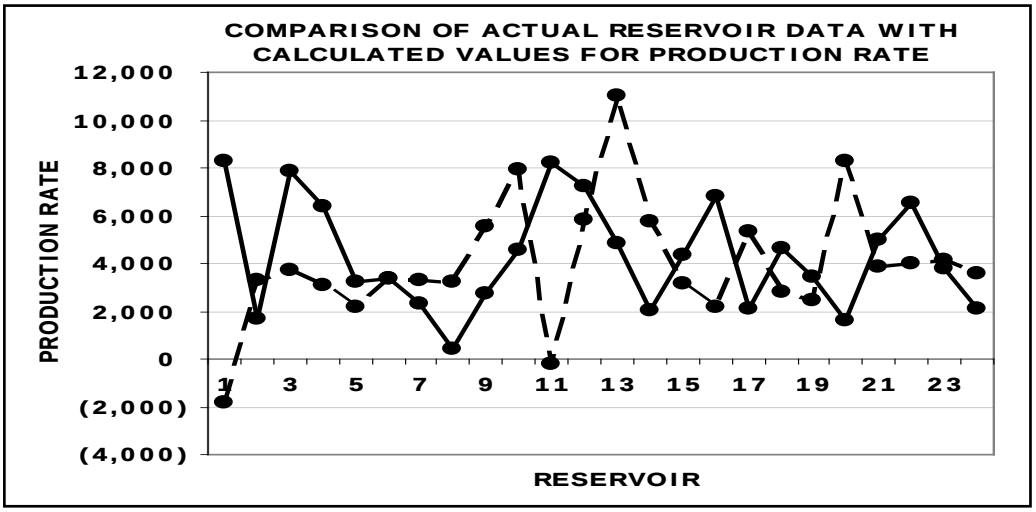


Figure 9: Comparison of Actual Reservoir Data with Simulated Values for Production Rate

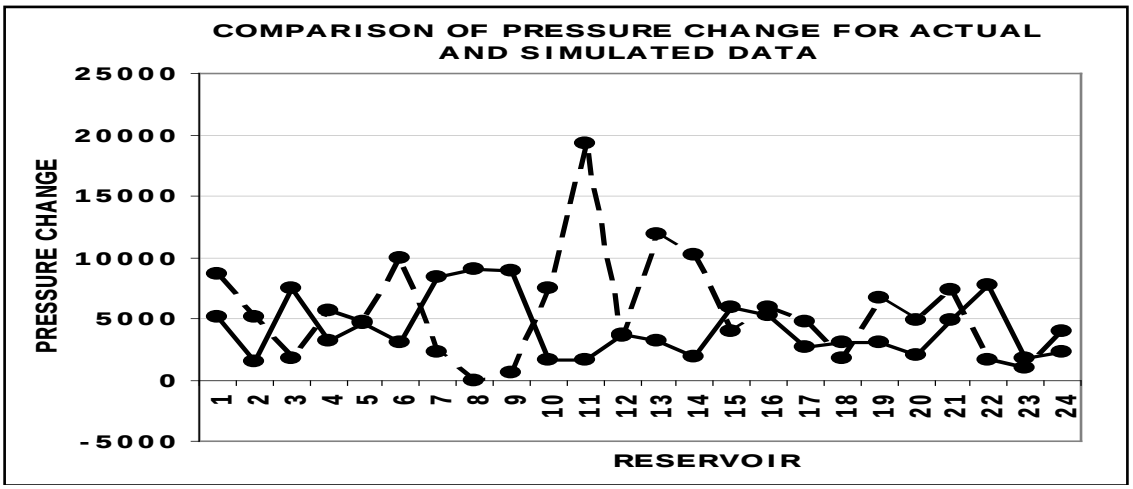


Figure 10: Actual Reservoir Data with Simulated Values for Pressure Change

Figure 10 and Fig 11 show the frequency distribution statistics for the multiple injection runs with particular classes of production and pressure for multiples simulation injection run. Figure 10 pressure change is shown by peak maxima and minima for injection group 1-24 considered for the reservoir system. A profile of Figure 11that closely resembles frac pressure data and the peak maxima and minima per injection run

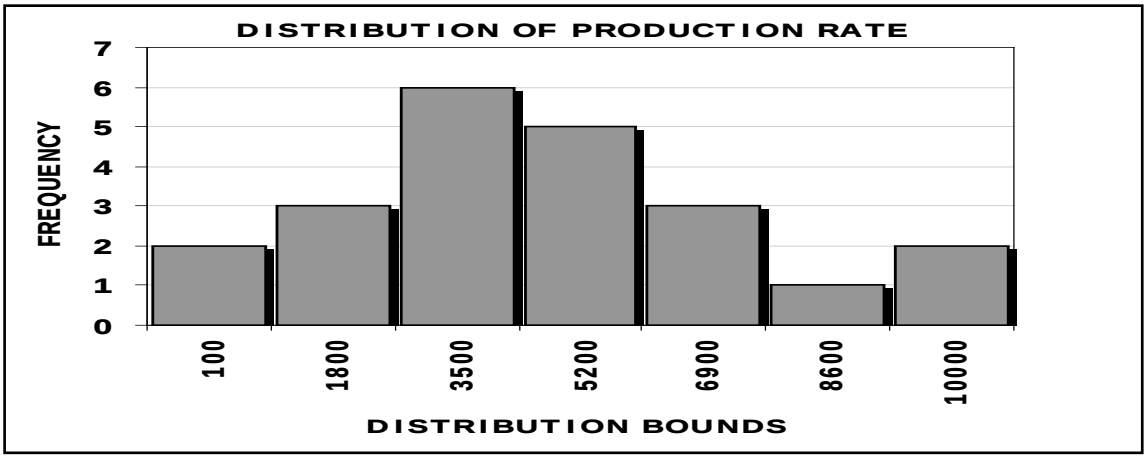


Figure 11: Frequency Distribution of Production Rate for Each Injectivity Group

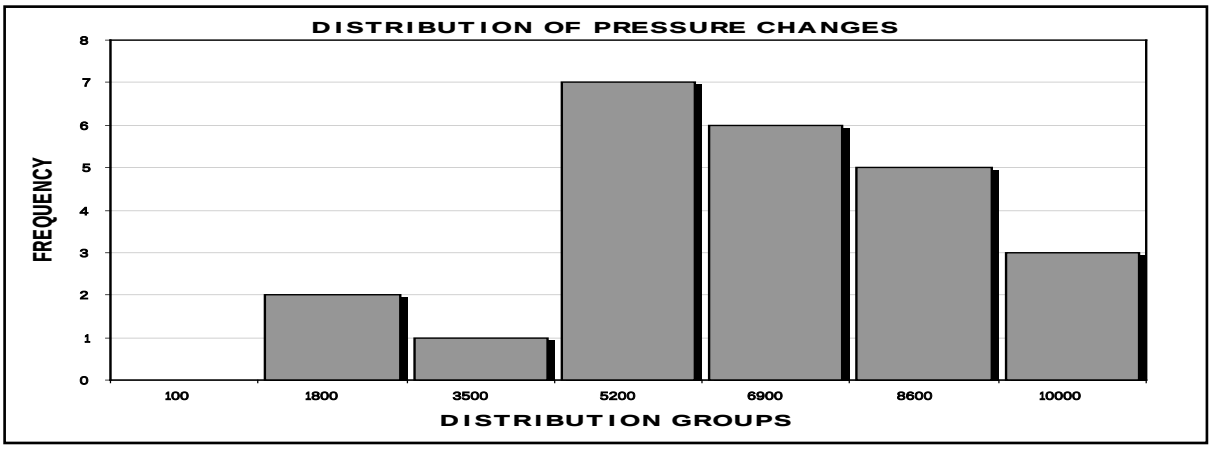


Figure 12: Frequency Distributions of Pressure Changes for Each Injectivity Group

Excel Sheets show the data categorization of variables in Table 5.0. The Monte Carlo model is applied to available reservoir data to study stochastically the pressure performance for several water injection rates for reservoir performance. The pressure changes normalized within a normal distribution thresholds is use to represent different probability scenarios for different injection rate schemes. This calculation also achieved with MS Excel functions required the calculation of the mean and standard deviation of the set of pressure changes for the different reservoirs. The data are represented using simulation random numbers generated to replicate the probability calculated for each of the above pressure change. The results show probabilities is a normal distribution are between 0 and 1, random numbers were generated to lie between 0 and 1 also. MS Excel functions were then written to achieve an inversion of the simulated probability values to pressure changes. To ensure that the simulated values keep dimensions with the actual reservoir data, the mean and standard deviation calculated for the actual data were employed for the inversion. The regression analysis for the field data below is presented in Fig 13 .The regression statistics show multiple of R is 0.998476685, R Square is 0.99695569 and Adjusted R square is 0.919622802 and Standard error of 0.003468055 for the 60 observations shows a strong agreement with the Monte Carlo Simulation model and Field data.

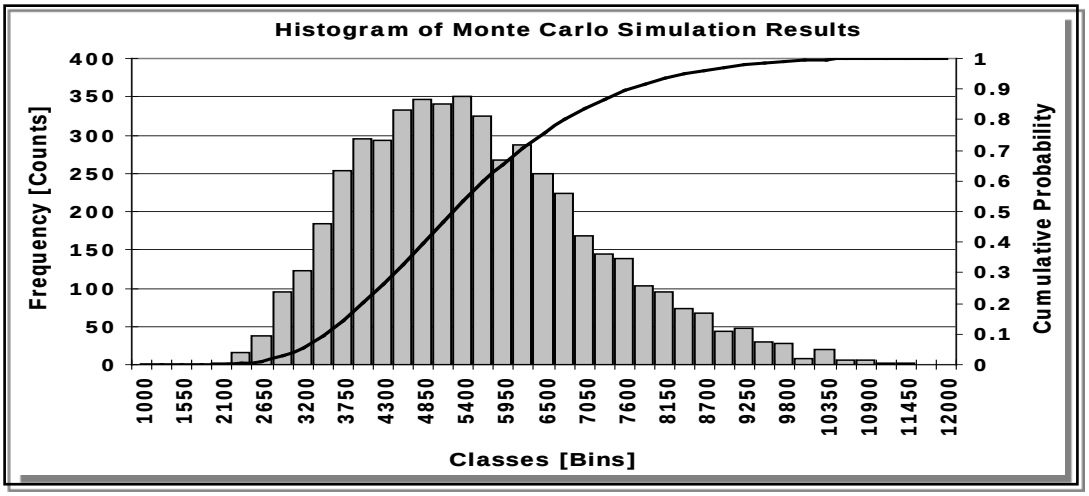


Figure 13: Histogram and Probability Distribution of the Monte Carlo Simulation

This results of simulation of field and production data obtained from the operator such as reservoir data of the study area, produced water parameters quality, factors which are responsible for cake formation and fracture formation is presented in Figure 13. Figure 13 is the data obtained from water reinjection indicates that calcite (calcium carbonate) forms the cake during the water reinjection process. From the graph showing the distribution of water reinjected parameters, it is observed that the amount of calcium and carbonate contained in the produced water is small relative to the other constituents and contributed majorly to cake formation.

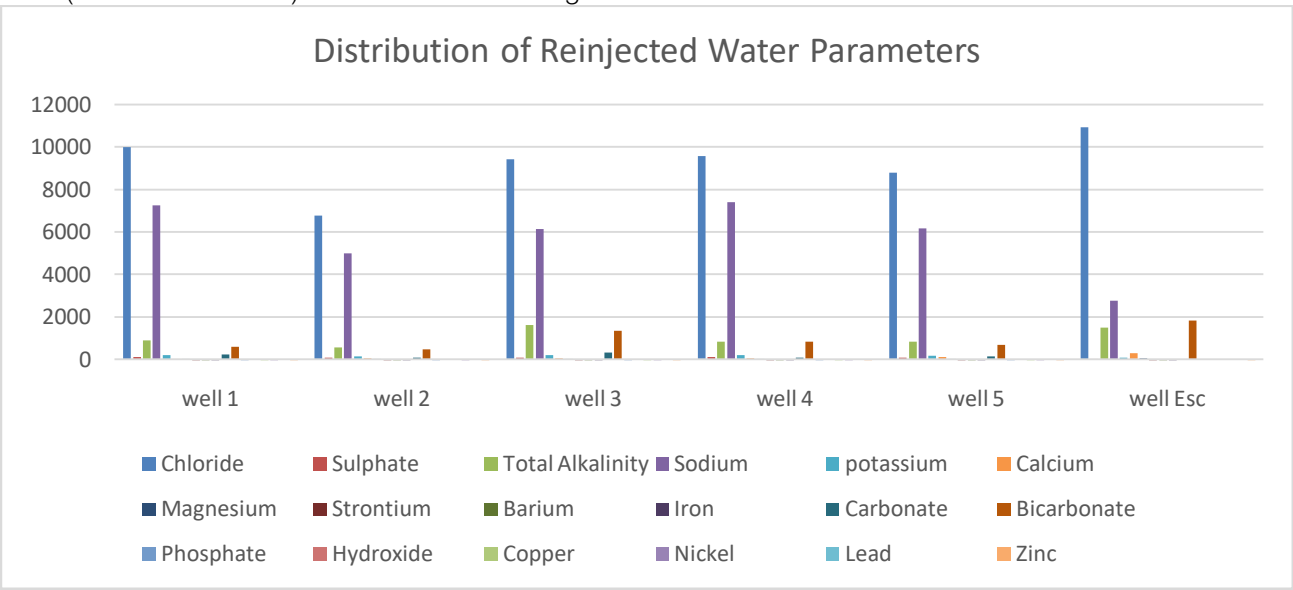


Figure 13: Chart for Distribution of Produced Water Parameters Quality in the Wells

b) Regression Analysis Output

Under the null hypothesis, the regression function does not depend on explanatory variables. The individual T statistic is used in calculating the P value which shows the statistical significance of the individual variables. An alpha level of 0.30 was used in this study. A P value less than the alpha level indicate a high statistical significance of the variable. A re-run regression analysis was performed to eliminate variables with high P values and insignificant regression coefficients. In this report, the Scaling Index (SI) which is used as an index of scaling in the formation resulting from produced water reinjection is the dependent variable prediction is based on temperature, pressure, pH, pH after precipitation and Injection rate. A high Multiple R value indicates a strong linear relationship existence. The Adjusted R squared value used in the regression analysis of this study is a multi linear regression. The regression analysis output from the field data is presented in Table 11

Table 11: Regression Analysis Output from Field Data for Well 10 Field X-10ST (Scenario1)

Regression Output Scenario 1

Regression Statistics	
Multiple R	0.991167
R Square	0.982411
Adjusted R Square	0.980412
Standard Error	0.003463
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.02948	0.005896	491.5183	2.04E-37
Residual	44	0.000528	1.2E-05		
Total	49	0.030008			

	Coefficients	*Standard Error*	*T Stat*	*P-Value*
Intercept	-2.16204	0.351959	-6.14286	2.08E-07
Temp	0.00116	0.001933	0.600312	0.551378
Pressure	5.76E-05	6.76E-05	0.851287	0.399219
pH	0.55999	0.037971	14.74792	1.22E-18
pH after	-0.01215	0.005895	-2.06095	0.045248
Injection rate	5.4E-09	1.6E-07	0.033702	0.973267

*SI = -2.16204 + 0.00116 * Temperature + 0.0000576 * Pressure + 0.55999 * pH – 0.01215 * pH after precipitation + 5.4E-09 * Injection Rate. Table 4.0 OS Re-Run regression output scenario 1*

Table 12: Re-Run Regression Output Scenario 1

Regression Statistics	
Multiple R	0.991166
R Square	0.982411
Adjusted R Square	0.980847
Standard Error	0.003425
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.02948	0.00737	628.3449	7.62E-39
Residual	45	0.000528	1.17E-05		
Total	49	0.030008			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2.17122	0.220229	-9.85893	8.1E-13

Temp	0.001162	0.001911	0.607929	0.546291
Pressure	5.76E-05	6.68E-05	0.862559	0.392954
pH	0.561117	0.017791	31.54021	2.5E-32
pH after	-0.0123	0.003793	-3.24242	0.002235

*SI = -2.17122 + 0.001162 * Temperature + 0.0000576 * Pressure + 0.561117 * pH – 0.0123 * pH after precipitation*

c) *Regression Analysis Output from Field Data for Well 12 Field X-12HST (Scenario 2)*

Table 13: Regression Output Scenario 2

Regression Statistics	
Multiple R	0.988244
R Square	0.976626
Adjusted R Square	0.97397
Standard Error	0.003595
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.023759	0.004752	367.6826	1.06E-34
Residual	44	0.000569	1.29E-05		
Total	49	0.024328			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2.08432	0.347215	-6.00297	3.34E-07
Temp	0.002274	0.002004	1.13481	0.262599
Pressure	9.93E-06	6.6E-05	0.150273	0.881236
pH	0.54543	0.035752	15.25596	3.5E-19
pH after	-0.01598	0.005797	-2.75678	0.008465
Injection rate	1.79E-08	1.67E-07	0.107264	0.915067

*SI = -2.08432 + 0.002274 * Temperature + 9.93E-06 * Pressure + 0.54543 *pH – 0.01598 * pH after precipitation + 1.79E-08 * Injection Rate*

Table 14: Rerun Regression Output Scenario 2

Regression Statistics	
Multiple R	0.988235186
R Square	0.976608784
Adjusted R Square	0.97508327
Standard Error	0.003517229
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	0.023758938	0.00791965	640.183386	1.67336E-37

Residual	46	0.000569062	1.2371E-05
Total	49	0.024328	

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2.134068821	0.15778	-13.525597	1.2145E-17
Temp	0.002584819	6.86134E-05	37.6722122	3.1818E-36
pH	0.548701518	0.016598371	33.057553	1.0517E-33
pH after	-0.016524371	0.003773413	-4.3791581	6.8162E-05

*SI = -2.13407 + 0.002585 * Temperature + 0.548702 * pH – 0.01652 * pH after precipitation*

d) Regression Analysis Output from Field Data for Well 13 Field X-13HST (Scenario 3)

Table 15 is the regression output for scenario 3

Table 15: Regression Output Scenario 3

Regression Statistics	
Multiple R	0.975719
R Square	0.952028
Adjusted R Square	0.946577
Standard Error	0.005013
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.021944	0.004389	174.6405	7.53E-28
Residual	44	0.001106	2.51E-05		
Total	49	0.02305			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept	-3.44031	0.667229	-5.15611	5.75E-06	-4.78502
Temp	0.006318	0.003042	2.077188	0.043654	0.000188
Pressure	-0.00011	9.94E-05	-1.09295	0.280366	-0.00031
pH	0.693906	0.070894	9.788002	1.29E-12	0.551029
pH after	-0.06126	0.012195	-5.0229	8.94E-06	-0.08583
Injection rate	5.18E-07	2.13E-07	2.430296	0.019233	8.85E-08

*SI = -3.44031 + 0.006318 * Temperature – 0.00011 * Pressure + 0.693906 * pH – 0.06126 * pH after precipitation + 5.18E-07 * Injection Rate*

Table 16: Rerun Regression Output Scenario 3

Regression Statistics	
Multiple R	0.972414
R Square	0.945589
Adjusted R Square	0.940752
Standard Error	0.005279
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.021796	0.005449	195.5079	7.96E-28
Residual	45	0.001254	2.79E-05		
Total	49	0.02305			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept	-4.60358	0.489533	-9.40402	3.44E-12	-5.58955
Temp	0.008126	0.003106	2.616268	0.012059	0.00187
Pressure	-0.00015	0.000103	-1.50154	0.1402	-0.00036
pH	0.827179	0.047315	17.48224	1.1E-21	0.731881
pH after	-0.08656	0.006688	-12.9415	9.01E-17	-0.10003

*SI = -4.60358 + 0.008126 * Temperature – 0.00015 * Pressure + 0.827179 * pH – 0.08656 * pH after precipitation*

e) Regression Analysis Output from Field Data for Well 18 Field X-18ST (Scenario 4)

Table 17: Regression Output Scenario 4

Regression Statistics	
Multiple R	0.997422
R Square	0.99485
Adjusted R Square	0.994265
Standard Error	0.003114
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.082423	0.016485	1699.89	3.83E-49
Residual	44	0.000427	9.7E-06		
Total	49	0.08285			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1.15459	0.32674	-3.53367	0.000977
Temp	-0.00441	0.001934	-2.28196	0.027384
Pressure	0.000274	7.36E-05	3.71952	0.000562
pH	0.491024	0.034478	14.24165	4.38E-18
pH after	-0.00445	0.006946	-0.64022	0.525348
Injection rate	2.42E-08	1.18E-07	0.204374	0.839004

*SI = -1.15459 – 0.00441 * Temperature + 0.000274 * Pressure + 0.491024 * pH – 0.00445 *pH after precipitation + 2.42E-08 * Injection Rate*

Table 18: Rerun Regression Output Scenario 4

Regression Statistics	
Multiple R	0.997314
R Square	0.994636
Adjusted R Square	0.994286
Standard Error	0.003108
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	0.082406	0.027469	2843.115	3.29E-52
Residual	46	0.000444	9.66E-06		
Total	49	0.08285			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1.10102	0.20865	-5.27688	3.45E-06
Temperature	-0.00485	0.001865	-2.59896	0.012524
Pressure	0.00029	7.15E-05	4.056664	0.000191
pH	0.485192	0.01795	27.0295	7.08E-30

*SI = -1.10102 – 0.00485 * Temperature + 0.00029 * Pressure + 0.485192 * pH*

f) Regression Analysis Output from Field Data for Well 26 Field X-26 (Scenario 5)

Table 19: Regression Output Scenario 5

Regression Statistics	
Multiple R	0.986538
R Square	0.973258
Adjusted R Square	0.970219
Standard Error	0.00287
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.01319	0.002638	320.2661	2.03E-33
Residual	44	0.000362	8.24E-06		
Total	49	0.013552			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.00585	0.425917	-0.01373	0.989111
Temp	-0.00014	0.001721	-0.08203	0.934997
Pressure	6.6E-05	5.65E-05	1.167831	0.249164
pH	0.32345	0.047651	6.787871	2.34E-08
pH after	0.003212	0.009405	0.341508	0.734347
Injection rate	7.46E-08	9.11E-08	0.818697	0.417372

*SI = -0.00585 – 0.00014 * Temperature + 6.6E-05 * Pressure + 0.32345 *pH + 0.003212 * pH after precipitation + 7.46E-08 * Injection Rate*

Table 20: Rerun Regression Output Scenario 5

Regression Statistics	
Multiple R	0.986282
R Square	0.972753
Adjusted R Square	0.971594
Standard Error	0.002803
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.013183	0.006591	838.9829	1.7E-37
Residual	47	0.000369	7.86E-06		
Total	49	0.013552			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept	-0.18532	0.252548	-0.73382	0.466704	-0.69339
Pressure	6.37E-05	3.56E-06	17.89608	1.29E-22	5.65E-05
pH	0.344549	0.027479	12.5384	1.33E-16	0.289267

*SI = -0.18532 + 6.37E-05 * Pressure + 0.344549 * pH*

g) Regression Analysis Output from Field Data for Field X (Scenario 6)

FIELD X

This scenario considers altogether the previous scenarios.

Table 21: Regression Output Scenario 6

Regression Statistics	
Multiple R	0.972378
R Square	0.945518
Adjusted R Square	0.944402
Standard Error	0.007245
Observations	250

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.222256	0.044451	846.9089	6.3E-152
Residual	244	0.012807	5.25E-05		
Total	249	0.235062			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1.45881	0.18627	-7.83165	1.47E-13
Temp	0.005211	0.000145	35.97596	1.5E-99
Pressure	-9.9E-05	5.15E-06	-19.2332	8.49E-51
pH	0.456151	0.021364	21.35138	9.3E-58
pH after	-0.02185	0.00452	-4.83319	2.38E-06
Injection rate	3.02E-07	9.03E-08	3.339175	0.000972

*SI = -1.4588 + 0.00521 * Temperature – 9.905E-05 * Pressure + 0.456 * pH – 0.02185 * pH after precipitation + 3.01545E-07 * Injection Rate*

h) Regression Analysis Output from Field Data for Field Y

Table 22: Regression Analysis on Rock Properties

Regression Statistics	
Multiple R	0.999199
R Square	0.998399
Adjusted R Square	0.998218
Standard Error	8.593554
Observations	60

ANOVA

	df	*SS*	*MS*	*F*
Regression	6	2440890	406814.94	5508.727
Residual	53	3914.006	73.849176	
Total	59	2444804		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-4151.74	79.70977	-52.08573	3.36E-47
Young's modulus, psi	-5.4E-07	3.29E-06	-0.163835	0.870484
Poisson's Ratio	5077.193	62.49606	81.240204	2.65E-57
Pressure, psi	1.892506	0.024376	77.637016	2.87E-56
Compressibility, psi-1	-576349	690414.7	-0.834786	0.407585
Permeability, md	0.006449	0.002004	3.2186398	0.0022
Porosity	-38.5441	33.04645	-1.166361	0.24869

*Shear Stress = - 4151.74 – 5.4E-07 * Young's Modulus + 5077.193 * Poisson's Ratio + 1.89 * Pressure – 576349 * Compressibility + 0.006449 * Permeability – 38.5441 * Porosity*

Table 23: Re-Run Regression Analysis on Rock Properties

Regression Statistics	
Multiple R	0.999199
R Square	0.998398
Adjusted R Square	0.99825
Standard Error	8.515768
Observations	60

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	2440887.7	488177.5	6731.783	3.77E-74
Residual	54	3915.9886	72.51831		
Total	59	2444803.7			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-4157.12	71.976823	-57.7564	3.14E-50
Poisson's Ratio	5074.787	60.197479	84.30232	5.32E-59
Pressure, psi	1.893951	0.0225194	84.10327	6.04E-59
Compressibility, psi-1	-541275	650444.08	-0.83216	0.408983
Permeability, md	0.006473	0.0019803	3.268503	0.001884
Porosity	-34.6017	22.444932	-1.54162	0.129005

*Shear Stress = - 4157.12 + 5074.787 * Poisson's Ratio + 1.89 * Pressure – 541275 * Compressibility + 0.006473 * Permeability – 34.6017 * Porosity*

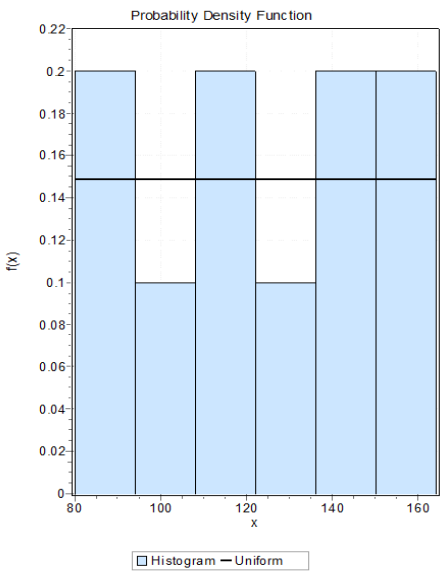
i) Monte Carlo Simulation

The Monte Carlo Simulation which are the probability distribution defines the best fit of the independent variables where each scenario was described.

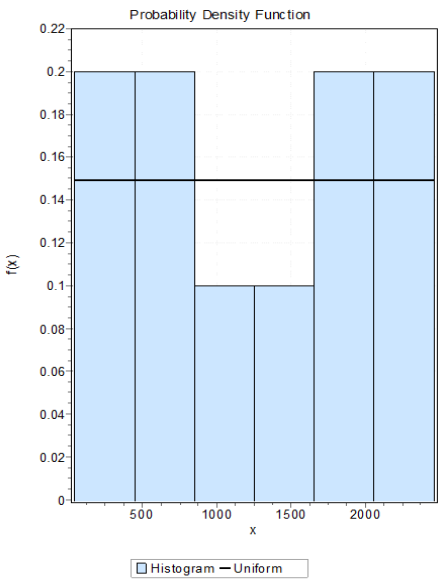
i. *Monte Carlo Probability Distributions*

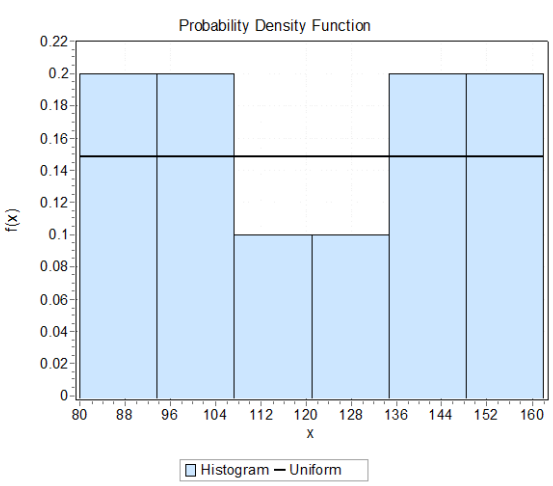
Scenario 1 – WELL 10

Temperature (Uniform)

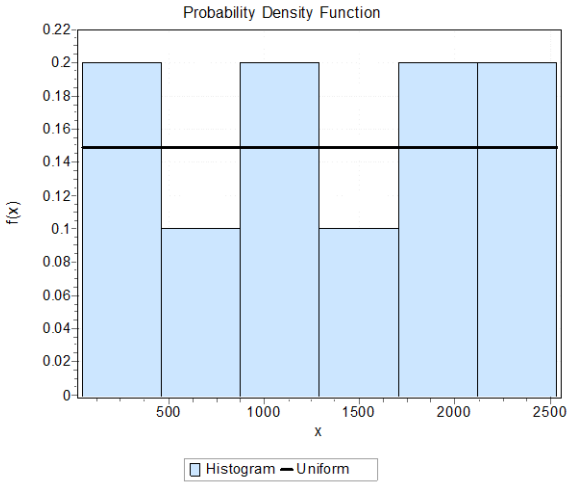


Pressure (Uniform)

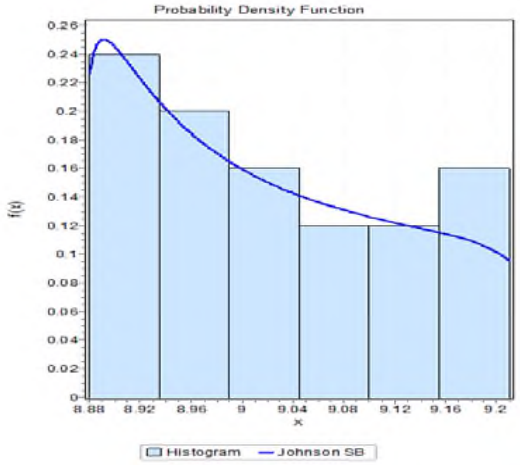


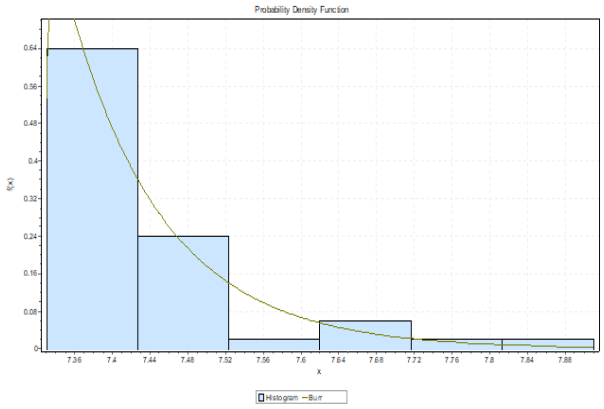


pH (Johnson SB)



pH after (Burr)





Injection Rate (uniform)

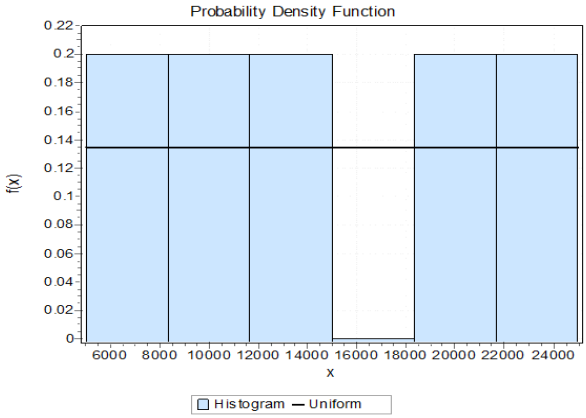


Figure 19: Probability Distribution Functions for Variables in Predicting SI in Well 18

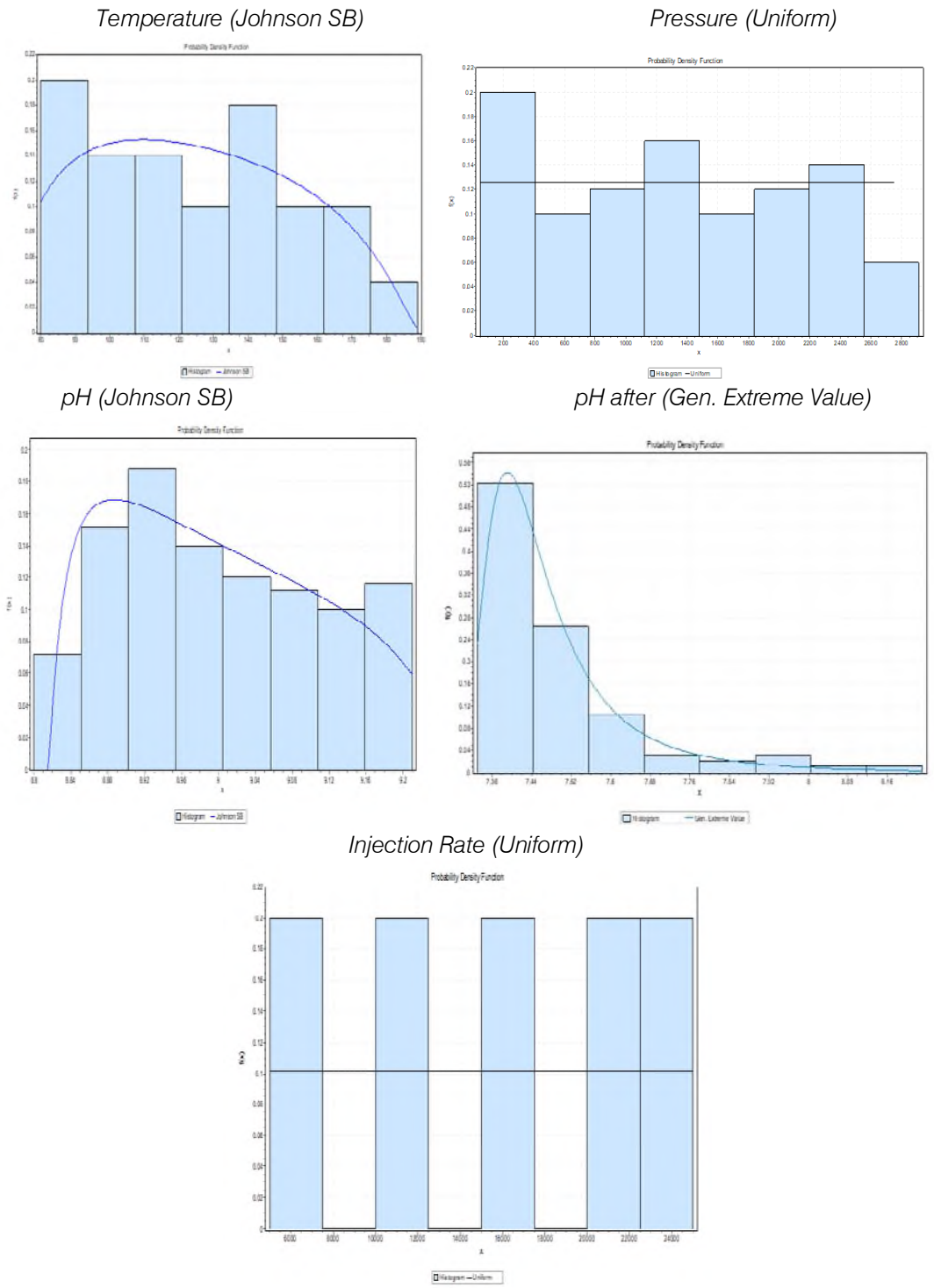


Figure 20: Probability distribution functions for variables in predicting SI in Field X

j) Simulations of Effects of Cake formation, fracturing on Injection Well Performance

The injector well performance was evaluated based on the injectivity index. An average value of 15,000 bbl/d was used as injection rate in calculating injectivity index based on average injection rates in the various wells of the Nigerian oil field. Based on the estimated values of Scaling Index (SI) from the Monte Carlo Simulation, Injectivity Index was then determined and various plots created.

In a number of thirty (30) simulation plots to model the effects of cake formation on injector well performance, it was observed in Scenario 1, that twenty-five (25) simulation plots indicated a decreasing trend in well performance, four (4) indicated a constant trend in the injection well performance and one (1) indicated an increasing trend in well performance based on

increasing cake formation. In Scenario 2, it was observed that twenty-eight (28) simulation plots indicated a decreasing trend in well performance, zero (0) indicated a constant trend in the injection well performance and two (2) indicated and increasing trend in well performance based on increasing cake formation. In Scenario 3, it was observed that twenty-seven (27) simulation plots indicated a decreasing trend in well performance, and three (3) indicated a constant trend in the injection well performance based on increasing cake formation. In Scenario 4, it was observed that twenty-six (26) simulation plots indicated a decreasing trend in well performance, two (2) indicated a constant trend in the injection well performance and two (2) indicated an increasing trend in well performance based on increasing cake formation. In Scenario 5, it was observed that twenty-five (25) simulation plots indicated a decreasing trend in well performance, and five (5) indicated an increasing trend in well performance based on increasing cake formation. In Scenario 6, it was observed that all thirty (30) simulation plots indicated a decreasing trend in well performance, based on increasing cake formation. A tabulated expression is seen in *Appendix B1.* Appendix B1show the simulations that there were occasions when Injectivity index was very high which indicated high well performance before a decline. This could be likened to a result of computer generated low values of flowing wellbore pressure.

k) Simulations of Effect of Fracturing on Injector Well Performance

The table below shows the simulation data for evaluating the effect of fracturing on the Injector Well Performance for a Field Y in the Gulf of Mexico.

Table 24: Simulation Data for Fracturing Effect on Injector Well Performance in Field Y Gulf of Mexico

Parameter	Values
Reservoir Pressure, Pe	5000 psia
Maximum Shear Stress	2500 psi
Fluid Shear Stress	1671.315 psi
Wellbore Flowing Pressure, P_{wf}	Simulated
Injection Rate	15,000 bbl/d

A K_{fs} value of 0 indicates rock fracture propagation while a K_{fs} value of 1 indicates least fracture propagation. A simulation plot of Injectivity Index against rock fracture production Rate is illustrated below.

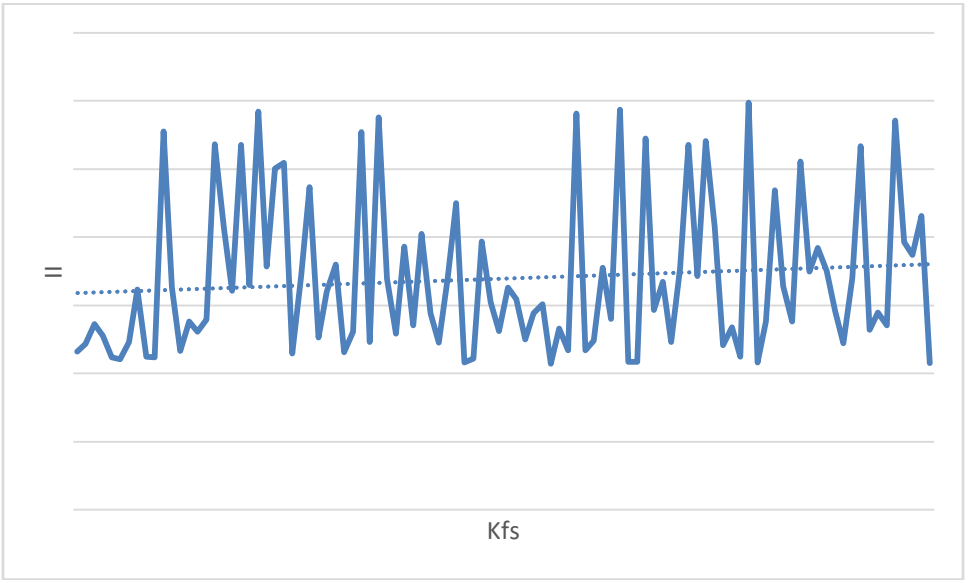


Figure 21: Simulation Plot (10) for Field Y in Gulf of Mexico

To model the effect of rock fracture propagation rate on Injector Well Performance, fifty (50) simulation plots were run. It was observed that seven plots (7) indicated a decline, seven (7) indicated a constant and thirty-six (36) indicated an increase in Injector Well Performance with increasing value of Kfs i.e. decreasing rock fracture propagation rate which implies more fluid flow.

V. Conclusion

In the formation of the hypothesis, five explanatory variables: Temperature, Pressure, pH, pH after precipitation and Injection rate were used to create a statistical regression analysis model for the prediction of Scaling Index (SI). Hence, it is suggested that all the five explanatory variables be used in creating a model. The Monte Carlo simulations ran all indicated SI values greater than 0 in all scenarios indicating potential for scale formation. SI = < 0 indicates no potential for scaling and SI = > 0 indicates scaling potential. In predicting fracturing, the rock shear stress and maximum shear stress were evaluated and fracturing can occur when the fluid shear stress is greater than the residual stress from the maximum rock stress and rock shear stresses at a depth. Based on the Simulation Plots obtained from the Program, a range of 83.3% - 100% indicated that formation of cake leads to decline in Injection Well Performance and 72% indicated that decrease in the rock fracture propagation rate corresponds to an increase in Injector Well Performance. Furthermore for each temperature, the SI decreases as the pressure increases and based on field data the regression statistics show R to be 0.998476685, R Square to be 0.99695569 and Adjusted R square is 0.919622802 and standard error of 0.003468055 for the observations shows a strong agreement with field data.

Nomenclature

q = Production Rate	bbls/day
k = Permeability	Darcy
A = Cross section area	m^2
μ = Fluid viscosity	Kg/m.s
$\frac{\Delta P}{L}$ = Pressure gradient (Pressure change per unit length).	Pascal/m

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Declaration of Interest

"The authors have nothing to declare"

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A5: Field Data for Well 26 Field X-26

SI	Temp	Pressure	pH	pH after	Injection rate
2.99	80	50	9.2	7.91	5000
2.99	89	326	9.14	7.58	5000
2.99	98	602	9.1	7.51	5000
2.99	107	878	9.06	7.47	5000
2.99	116	1154	9.02	7.44	5000
3.00	126	1430	8.98	7.42	5000
3.01	135	1706	8.95	7.41	5000
3.01	144	1982	8.92	7.41	5000
3.02	153	2258	8.9	7.41	5000
3.03	162	2534	8.88	7.41	5000
2.99	80	50	9.21	7.77	10000
2.99	89	326	9.15	7.52	10000
2.99	98	602	9.11	7.46	10000
2.99	107	878	9.06	7.43	10000
3.00	116	1154	9.03	7.4	10000
3.00	126	1430	8.99	7.38	10000
3.01	135	1706	8.96	7.37	10000
3.02	144	1982	8.93	7.36	10000
3.03	153	2258	8.91	7.36	10000
3.04	162	2534	8.88	7.36	10000
2.99	80	50	9.21	7.7	15000
2.99	89	326	9.16	7.5	15000
2.99	98	602	9.11	7.44	15000
3.00	107	878	9.07	7.41	15000
3.00	116	1154	9.03	7.38	15000
3.01	126	1430	9	7.37	15000
3.01	135	1706	8.96	7.36	15000
3.02	144	1982	8.94	7.35	15000
3.03	153	2258	8.91	7.34	15000
3.04	162	2534	8.89	7.34	15000
2.99	80	50	9.21	7.66	20000
2.99	89	326	9.16	7.48	20000
2.99	98	602	9.11	7.43	20000
3.00	107	878	9.07	7.4	20000
3.00	116	1154	9.03	7.38	20000
3.01	126	1430	9	7.36	20000
3.01	135	1706	8.97	7.35	20000
3.02	144	1982	8.94	7.34	20000
3.03	153	2258	8.91	7.34	20000
3.04	162	2534	8.89	7.33	20000
2.99	80	50	9.21	7.63	25000
2.99	89	326	9.16	7.47	25000
2.99	98	602	9.11	7.43	25000
3.00	107	878	9.07	7.4	25000
3.00	116	1154	9.03	7.38	25000
3.01	126	1430	9	7.36	25000
3.01	135	1706	8.97	7.34	25000

3.02	144	1982	8.94	7.34	25000
3.03	153	2258	8.91	7.33	25000
3.04	162	2534	8.89	7.33	25000

A6: Field Data For Well In Gulf Of Mexico

TVD	σHmin	σHmin/TVD	Young's modulus, psi	Poisson's Ratio	Toughness, psi-in1/2	Pressure, psi	Compressibility, psi-1	Permeability, md	Porosity	Formation Fluid	Coeff of Therm Exp (1/R)	Temp(F)	Biots Constant
2133.64	3750	1.75756	92000	0.392	400	3134	1.05E-05	100	0.343	0.7	3.50E-06	95.6	1
2134.29	3751	1.757493	86000	0.392	400	3134	1.07E-05	100	0.386	0.7	3.50E-06	95.6	1
2134.43	3752	1.757846	180000	0.392	400	3134	1.03E-05	100	0.393	0.7	3.50E-06	95.6	1
2134.57	3752	1.757731	350000	0.392	400	3135	1.05E-05	100	0.35	0.7	3.50E-06	95.7	1
2134.72	3729	1.746833	7.70E+05	0.386	400	3135	9.53E-06	100	0.216	0.7	3.50E-06	95.7	1
2135.57	3657	1.712423	2.30E+06	0.368	400	3135	3.65E-06	100	0.117	0.7	3.50E-06	95.7	1
2135.86	3790	1.774461	1.10E+06	0.4	400	3136	3.27E-06	100	0.274	0.7	3.50E-06	95.7	1
2139.29	3795	1.773953	4.60E+05	0.4	400	3138	5.82E-06	100	0.314	0.7	3.50E-06	95.9	1
2140.72	3726	1.740536	1.00E+06	0.383	400	3141	5.48E-06	100	0.295	0.7	3.50E-06	96.1	1
2142.58	3906	1.823036	2.60E+06	0.421	400	3143	3.34E-06	100	0.15	0.7	3.50E-06	96.2	1
2142.86	3890	1.815331	1.10E+06	0.418	400	3145	4.76E-06	100	0.291	0.7	3.50E-06	96.3	1
2146.15	3691	1.719824	3.70E+05	0.371	400	3147	5.70E-06	100	0.308	0.7	3.50E-06	96.4	1
2147.86	3785	1.762219	7.20E+05	0.391	400	3150	4.31E-06	100	0.289	0.7	3.50E-06	96.6	1
2148.29	3884	1.80795	2.70E+05	0.413	400	3151	5.52E-06	100	0.351	0.7	3.50E-06	96.6	1
2166.76	3895	1.797615	1.20E+05	0.411	400	3163	6.10E-06	100	0.371	0.7	3.50E-06	97.3	1
2167.34	3778	1.743151	2.90E+05	0.379	400	3174	6.37E-06	100	0.265	0.7	3.50E-06	98	1
2175.37	3775	1.735337	4.70E+05	0.376	400	3180	4.63E-06	100	0.31	0.7	3.50E-06	98.3	1
2185.71	3878	1.774252	1.90E+05	0.394	400	3191	6.93E-06	100	0.331	0.7	3.50E-06	99	1
2194.96	3903	1.778165	9.20E+04	0.394	400	3203	9.13E-06	1500	0.358	0.7	3.50E-06	99.7	1
2205.51	3937	1.785075	1.00E+05	0.397	400	3215	8.62E-06	1500	0.347	0.7	3.50E-06	100.4	1
2208.97	3948	1.787258	4.20E+05	0.395	400	3224	6.09E-06	100	0.32	0.7	3.50E-06	100.9	1
2209.84	4122	1.865293	8.70E+05	0.429	400	3226	3.72E-06	1500	0.295	0.7	3.50E-06	101	1
2210.13	4195	1.898078	3.90E+05	0.443	400	3227	5.81E-06	1500	0.285	0.7	3.50E-06	101.1	1
2210.42	4100	1.854851	1.50E+05	0.425	400	3227	9.06E-06	1500	0.307	0.7	3.50E-06	101.1	1
2221.17	4046	1.821563	8.90E+04	0.411	400	3234	9.56E-06	1500	0.308	0.7	3.50E-06	101.5	1
2221.32	4003	1.802082	1.90E+05	0.4	400	3241	9.24E-06	1500	0.29	0.7	3.50E-06	101.9	1
2221.46	4020	1.809621	3.50E+05	0.403	400	3241	8.56E-06	1500	0.278	0.7	3.50E-06	101.9	1
2221.75	4023	1.810735	8.80E+05	0.404	400	3241	5.68E-06	1500	0.212	0.7	3.50E-06	101.9	1
2222.33	4025	1.811162	1.50E+06	0.404	400	3242	4.00E-06	1500	0.186	0.7	3.50E-06	101.9	1
2222.48	4026	1.81149	5.20E+05	0.404	400	3242	7.16E-06	1500	0.246	0.7	3.50E-06	102	1
2222.63	4039	1.817217	2.70E+05	0.406	400	3242	6.99E-06	1500	0.254	0.7	3.50E-06	102	1
2233.68	4078	1.825687	8.70E+05	0.411	400	3249	9.14E-06	1500	0.311	0.7	3.50E-06	102.4	1
2234.7	3933	1.759968	2.60E+05	0.378	400	3257	4.33E-06	1500	0.293	0.7	3.50E-06	102.8	1
2236.3	4070	1.81997	5.30E+05	0.405	400	3259	3.67E-06	1500	0.213	0.7	3.50E-06	102.9	1
2238.63	4338	1.937792	8.20E+05	0.454	400	3262	5.11E-06	1500	0.284	0.7	3.50E-06	103.1	1
2239.51	4038	1.803073	2.50E+05	0.397	400	3264	4.17E-06	1500	0.329	0.7	3.50E-06	103.2	1
2239.95	3942	1.759861	6.10E+05	0.377	400	3265	3.43E-06	1500	0.32	0.7	3.50E-06	103.2	1
2241.71	4119	1.837437	2.50E+06	0.411	400	3267	3.81E-06	1500	0.175	0.7	3.50E-06	103.3	1
2242.15	4320	1.926722	1.10E+06	0.449	400	3268	3.23E-06	1500	0.283	0.7	3.50E-06	103.4	1
2245.38	4224	1.881196	5.30E+05	0.431	400	3271	3.56E-06	1500	0.258	0.7	3.50E-06	103.5	1
2251.54	4281	1.901365	2.40E+05	0.439	400	3278	3.94E-06	1500	0.318	0.7	3.50E-06	103.8	1
2251.98	4333	1.924085	6.80E+05	0.446	400	3283	3.33E-06	1500	0.261	0.7	3.50E-06	104.1	1
2252.86	4366	1.937981	2.30E+06	0.451	400	3284	3.33E-06	1500	0.143	0.7	3.50E-06	104.1	1
2253.01	4312	1.913884	1.30E+06	0.442	400	3285	3.25E-06	1500	0.156	0.7	3.50E-06	104.2	1
2253.15	4313	1.914209	7.50E+05	0.442	400	3285	3.46E-06	1500	0.2	0.7	3.50E-06	104.2	1
2255.94	4123	1.82762	3.20E+05	0.406	400	3287	3.70E-06	1500	0.311	0.7	3.50E-06	104.3	1
2256.38	4235	1.8769	9.90E+05	0.427	400	3290	5.31E-06	1500	0.21	0.7	3.50E-06	104.4	1
2257.99	4411	1.953507	2.20E+06	0.457	400	3291	3.14E-06	1500	0.206	0.7	3.50E-06	104.5	1
2259.02	4134	1.829997	1.10E+06	0.407	400	3293	3.28E-06	1500	0.206	0.7	3.50E-06	104.6	1
2259.76	4149	1.836036	1.80E+06	0.409	400	3295	3.19E-06	1500	0.251	0.7	3.50E-06	104.6	1
2261.81	4104	1.814476	7.60E+05	0.4	400	3297	3.73E-06	1500	0.266	0.7	3.50E-06	104.7	1
2264.89	4025	1.777128	5.20E+05	0.382	400	3300	3.86E-06	1500	0.258	0.7	3.50E-06	104.9	1
2272.81	4197	1.846613	3.40E+05	0.413	400	3309	3.78E-06	100	0.3	0.7	3.50E-06	105.3	1
2273.7	4159	1.829177	2.10E+05	0.404	400	3315	5.63E-06	100	0.307	0.7	3.50E-06	105.6	1
2275.6	4207	1.848743	3.90E+05	0.412	400	3317	3.48E-06	100	0.334	0.7	3.50E-06	105.7	1
2288.77	4205	1.837231	2.70E+05	0.408	400	3329	3.73E-06	100	0.316	0.7	3.50E-06	106.3	1
2289.51	4313	1.883809	4.40E+05	0.425	400	3339	3.41E-06	100	0.277	0.7	3.50E-06	106.8	1
2291.88	4266	1.861354	1.80E+05	0.416	400	3342	3.88E-06	100	0.353	0.7	3.50E-06	106.9	1
2295.44	4281	1.865002	4.50E+05	0.417	400	3346	3.84E-06	100	0.293	0.7	3.50E-06	107.1	1
2316.41	4182	1.80538	3.80E+05	0.392	400	3364	3.56E-06	100	0.312	0.7	3.50E-06	108	1

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PMBOK 7th Edition, in the Good Direction, but How Effective?

By José Figueiredo
Universidade de Lisboa

Abstract- In conceptual terms, PMI new edition of PMBOK is aligned with values and principles at the edge of the social sciences, neurosciences, and information sciences of our days. As things change faster and predictability shortens a de facto standard should allow for a higher degree of interpretation, letting each approach be tailored by the context of each case. We focus on this stimulating paradigm shift from edition 6 to edition 7 of PMBOK with the aim of strengthening and making it more actionable. We believe we are contributing to the clarification of intents.

Keywords: *6th PMBOK Edition, 7th PMBOK Edition, tailoring, value, domains, tacit knowledge.*

GJRE-J Classification: *LCC: HD30.28*

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I. Introduction

Project Management Institute (PMI) provided a paradigmatic change to its project management guidefrom the 6th to the 7th edition. This paradigm shift of PMBOK is very welcome, but it is still open to many opportunities of improvement. The introduction of 'principles' as core concept is very interesting, but needs careful presentation and contextualization. It should be more explained and clearly addressed. The shift from processes to principles and from knowledge areas to domains carries with it a deep culture innovation. It cannot just be mentioned, it must be understood and internalized[1] (Nonaka et al., 2000). New concepts cannot be imposed dogmatically, by prescription [2] (Emel, 2012). Paradigm shifts are difficult social processes and, if mishandled, can end up destroying a wealth of opportunity. This suggests that we should work longer on the concepts and clear the message [3] (Polani, 1958). We may have to introduce new concepts and strengthen their coherence with contextual narratives[4] (Elain, 2016).

In the text of PMBOK 7th Edition, the principles are presented in a very confusing way. There is no effective explanation of the deep meaning of what principles represent in the context of project management, and each principle is not clearly explained. It is also not explained why we address principles. Furthermore, being a new concept in what we intend to be a new project management approach paradigm, they are referred in random order along the text. The same thing occurs with the domains. It is crucial to explain why we address domains instead of knowledge areas, but that explanation is not provided. So, it results unclear the crucial importance of addressing domains, how important they are in an integrative assertion of the concept. To be sound, the thesis of this new paradigm approach to PMBOK must be conceptually more robust, more clear and precise. We need to put a stronger effort into making the new approach more intuitive, attractive, and above all more clear.

A lot more work must also be done in other perspectives. The overall idea is that when "teaching" or orienting, guiding project managers to be systemic and proactive, based on principles, and value oriented concerns, evolving from knowledge areas to domains … the PMI narrative is prescriptive in a sense that is not effective [5] (Bergenholtz and Gouws, 2011). If we say that something must be done this way but don't explain why, giving examples, metaphors, meanings, we increase the risk of not being followed. PMI is definitely moving in the right direction but should make an effort to be more effective, explaining why this paradigm shift is important and producing a clear guide that could help people shifting from one paradigm to the other. We must always remember we all tend to resist change, [6] Val and Fuentes (2003), [7] Goldstein (1988), so, only if we are very convincing and persuasive we can act as change agents.

The "teaching" narrative strategy should be avoided and adapt to another paradigm shift, that of passing from "teaching" to "learning", [8] Bloom et al (1956), [9] Barr and Tagg (1995), [4] Elain (2016). In a fast changing unpredictable world, we need to evolve from teaching to learning[10] (Drucker, 1980),[9] (Barr and Tagg, 1995). Prescribing is teaching and it is not effective[4] (Elain, 2016). The only way to be productive in a community of project managers is to work on the background, indirectly, to help construct communities that reflect, discuss, engage in controversies, in a learning process able to produce and report results. Project managers need to tune up a team, stressing what is more important and effective to coordinate this team and make it effective so they have to internalize the meaning of these new concepts very well.

PMI has this huge advantage of having a wide and well distributed clientele that can facilitate research and the ability to construct a sound body of knowledge If PMI engage in this kind of learning community process, orienting PMs to develop themselves in a reflective practice it would be not only more effective,

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but much more powerful. In our view, the direction of this change from the 6th Edition to the 7th Edition is very good, but, as it is, it does not look as effective as it could be. The narrative should be improved, and this is not a detail. It means getting to the roots of the learning processes and the mechanisms of the mind use to develop and learn, [11] Goodson and Scherto (2011), [12] (Goodson et. al. 2010).

Resuming, principles, values and domains, cannot be addressed in a prescription mode if we want to make them effective and useful. It would be a good choice to use stories, and engage in powerful metaphors and make their use in practice something conscient, in order to take the most of them and learn.

Tailoring, as PMI well propose for projects, should be extended to the intrinsic approach and narrative of the text of the guide itself. That is, the text need to be tailored to a more clear version. Besides, value and tailoring as we address it can only be understood in a cultural context, a Project Management cultural context.

Besides, as the paradigm shifted from industrial economies to knowledge economies, the importance of the project context in project management increased dramatically. The global economy shifted from trading materials to exploring mind. You can order and buy materials, change schedules, but in what concerns knowledge, mainly tacit knowledge, we are not on the list of what we can purchase. You need to develop it by yourself. In yourself and in your team by subjecting it to learning contexts. Tacit knowledge is developed by experiencing and reflecting[3] (Polanyi, 1958), and by being defied to explain yourself, something you develop when moving in controversies with interesting people, exploring the dynamic of groups, and taking advantage of teams. Always with a debate approach in a spirit where the politically correct attitude is not welcome.

A final remark in this introduction is about the term “optimization”. The use of this term is not accurate. Optimizing is guarantying that you achieve the best solution of them all, that is, your solution is better than all the others, all the others are guaranteed as worse. In the realm of Project Management, we should ban optimization from the vocabulary. We have no time to optimise when managing projects. Our purpose is not that one, our purpose is to be as effective as we can. That, of course, if our project is not about to optimize a process, or practice.

In this paper we focus on the stimulating paradigm shift promoted by the transition from edition 6 to edition 7 of PMBOK with the aim of strengthening this effort. We try to make it more understandable and clear. We would like to believe that we can contribute for the success of this journey. That is the main purpose of this paper.

II. Value and Tailoring

Let’s do an attempt to clarify our critical approach. Let’s take two distinctive concepts stressed on PMBOK 7th edition (2021). Value and Tailoring. Let’s try to insert them into a story to engage people on the perfect meaning they both have, and how important they really are for project managers. Stories and metaphors are the basic languages of learning and reflexion, they are in the roots of mankind and communities evolution through times[12] (Ivor et. al. 2010).

We have people who cannot read, they are analphabet, people who can read but don’t understand, illiterate people, people who read and understand, maybe the huge majority, but that can be still useless. In fact, we need two more stages in this progression to be effective. Beyond understanding we must internalize [13] (Nonaka and Takeuchi, 1995). This is about developing knowledge, tacit knowledge, not transferable knowledge. But the last stage is the one that finally adds value, it is about to be able to act. To transform information into action. This is the real value production.

The idea of being driven by value is much better, interesting, and effective then being driven by cost. Value has sustainability attached to it, it includes cultural and social dimensions, a systemic behaviour. Carlo Cipolla (1998) [14] was a bright Italian professor, expert in Middle Ages Economics, professor in Italy and in the United States, namely Professor emeritus in Berkley. He wrote many books on his expertise domain, but published one directed to us all, “The Basic Laws of Human Stupidity”. In a very short text, he uses a simple inspiring model to absorb what value is. This model is in itself a very effective narrative about value.

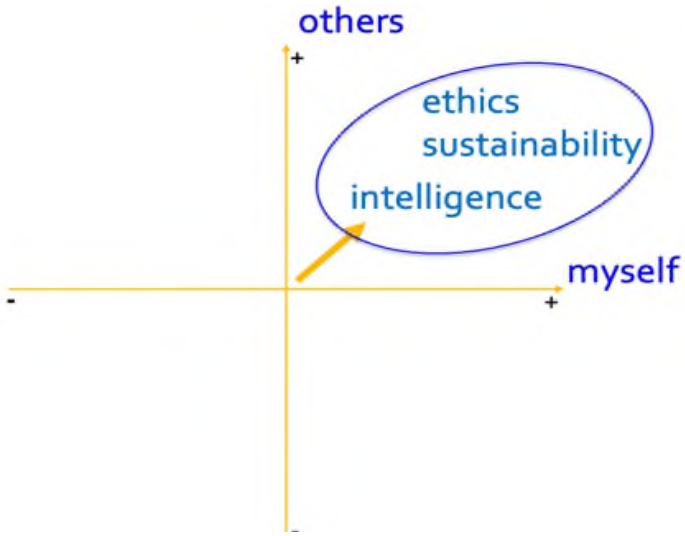

Figure 1: *Cipolla Value Model (1988)*

In figure 1, we have four quadrants formed by the cross of the two axes. One axis represents the impact of our action on ourselves (it can be positive or negative) and in the other axis we represent the impact of our actions on the others (it can be positive or negative). If your actions are good for yourself and bad for the others you are like a bandit, a cheater. If your actions are bad for you and bad for the other, you are stupid. That is an interesting definition of stupid, someone who doesn't create value at all, at all. If your actions are good for the others and bad for you, you are naïf. If your actions are good for you, and for the others, you are intelligent, you are behaving in a sustainable way, you are creating value for all, you are being effective.

This is a concept of value that is visited through its meaning, using a story, a metaphor, a model, and not addressed as a top down idea. We can as well illuminate the same concept with another story.

The author of Critical Chain, (1997) [15] the project management methodology, is an accomplished writer who writes novels. These novels are very inspiring in pointing you towards action. Critical Chain was basically a novel, and it was so powerful in terms of a subjacent project management methodology that the author and other people in Project Management decided to extend the book reasoning and develop a sound methodology – Critical Chain. Goldrat also have a book on value, "Necessary but not Sufficient" (2005) [16]. It is about the value ERPs bring to business and how easy is to develop and produce systems that end up not providing value for the firm. This story is also powerful in terms of metrics. How should we measure value? Cost and time can be only numbers, but value is a much more accomplished concept and needs another degree of conceptual reasoning, it needs a comprehensive context.

That is the kind of value we should try to create in the management of our projects, we tried to describe the kind of actions we should plan and execute to provide this kind of value. Our focus should always be in that quadrant of good outcomes for all, if possible. We let the reader of this text to imagine exceptions, because there are exceptions. Our concern should be about creating value for all, but we know that sometimes this is wishful thinking. Not a reason to not try.

Of course, we should be very concerned with cost, time and performance, but we should be guided by value, the general principle. Principles kind of encapsulate our actions, our practices, our processes and activities. For example, to measure medical effectivity by the number of patients consulted in a day would provide a wrong bias.

PMI, in the 7th edition of PMBOK (2021), also stresses tailoring. In fact, to improve our project culture, we should tailor our project habits, work on habits of effectiveness, according to an evolving progress and a context of action. This is a step-by-step learning process. We learn to adapt our knowledge, habits, guesses, intuition, reasoning, creativity, and critical thinking to specific cases, a specific project.

As far as tailoring is concerned, managing projects obliges us to see the tree and the forest, to be able to identify things in a micro setting, a space of details, and a macro setting, a wider space of integrated context, or environment. If we want to understand something deeply, we need to train this bifocal approach. Only by integrating the two views can we refine and align our actions in a wider understanding of the system, being intelligent agents of value creation and sustainability.

III. Stewardship Attitude

The stewardship attitude is also very important. As humanity evolved from a rural economy to an

industrial economy, into a knowledge economy, we also changed our relationship with work[17] (Sennett, 2008). In the rural ages, work was mainly handicraft in the production of direct goods, artefacts to the producer's use and food to heat. At that time even trade was unusual. At that stage of our working development, we learned directly with the others, looking at what the older people (more experienced) did, how they did it, and experimenting ourselves. Our relationship with work was emotional, we were engaged by what we did, it was our life, usually without social restrictions, we worked with our own family, there were no dichotomies, social life and work were intertwined, [17] Sennett (2008).

Later, in the industrial age, our work became something separate, a separate reality, more abstract, without any emotion involved, most of the times doing what someone else told us to do, forgetting to think and reflect. We became flatter, [18] Latour (1993), with less cultural dimensions, we lost the habit of thinking by ourselves, deciding our own lives, we began to behave like herds. Nietzsche called it herd morality! See also Simon Williams (1998) [19].

That is the way we have entered the knowledge age, [10] Drucker (1980). Simple people, flat, in a knowledge age but with poor thinking abilities and reflection habits. Too specialized in little things, unable to see the tree and the forest, unable to put things in perspective. More and more unable to think conceptually.

That is the kind of attitude we all should rethink to change and reinvent. Like computers, we need a reset. We need to fight this pathology of normality, [20] Fromm (1953), each one of us needs to wake up, take responsibility, do what needs to be done, be alive, be logic, be creative, and be critical, [21] Brabandere (2021).

The stewardship attitude is represented by elements in the team that try to guide others in their work, if there are more experienced than them. Using the project management team we can play roles and circulate, now I stewardship you, after you stewardship me.

IV. Principles and Domains

Principles in project management shouldn't be prescriptive by nature. They are intended to guide the behaviour of people involved in projects in a soft way, an indirect way, based on practices, processes, defined and accepted by the team. It is difficult to impose these practices with rules, and with prescriptions. To integrate the principles in your action we need to internalize them before. And this is a knowledge creating activity (Nonaka and Takeuchi, 1995) . Only deep reflection mixed with practice will help here. Should we abandon processes in managing projects to begin using principles? No, it would be impossible and, hopefully, not what PMI wants. But PMI is not clear because it doesn't address processes anymore. With the 7th edition of PMBOK we still use processes, plan processes, and execute processes. And even the management process groups are kept inline. PMBOK just suggests that internalizing the principles in a higher perspective you will act accordingly, within a purpose. Many mistaken positions about this can already be found in various texts and papers published about PMBOK 7th edition (2021).

Principles should be envisaged as general reference lines for behaviour. They provide a different way of performing activities, because they align these activities with a general goal. Consider, for instance, a project to produce a technological artefact. Without principles, we can plan and develop the project in ways that produce an artefact that is not safe for children use, and that heavily pollutes the environment. With a sustainability principle driving us, all the planning and execution of the project provide activities that guarantee the final result is neither dangerous for children, nor harmful for the environment. That is the way principles act on processes and activities. By the way, the principle of sustainability might be a good addition to PMBOK 7th edition.

"Descartes Error", the book by [22] Damasio (1994), which is also a research that has been evolving for more than forty years, in the fields of neurosciences, psychology and the brain, shows us that to be successful we must be able to reconcile rationality with emotion. To divide in order to understand is not a good strategy when we deal with complexity and complex systems. Systems are not the sum of their parts, and sometimes they are not even similar to their parts in terms of behavior and even matter.

And, in order to reason, we need whole persons, rationalists with emotion, people who are able to practice deductions and inferences and explore abduction and guessing, people who are able to educate their intuition with experience and reflection. Guessing, conjecturing, are welcome practices in science, as they are fundamental in project management.

People cannot act by mere reasoning. Reasoning live in contexts, if not in the context of specific settings reasoning produces automata. People must be able to learn by doing, continually, and when they learn by doing they can extrapolate from the principles, they have grown up during their conscient lives, to action, [23] Sadler and Zeidler (2005). They can mold their actions according to the specificity of the circumstances. This is also tailoring of action, [24] Boytsov (2011).

So, we need new people, alive people, creative people, not people who live sleeping, like zombies, like Nietzsche's herds. We need creative people, who can be logical and know how to reason, but who can also be

creative and able to think out of the box, to explore new dimensions. And they must be critical, able to excel in systemic and critical thinking. If we are able to facilitate the flourishing of this kind of person in our teams, we will be able to reach excellence. If not, we are just preparing change for nothing, because no principles, nor anything else, will be internalized and made effective. We will be carrying out wishful thinking, not action.

In the context of or reasoning, the domains are a logical result. Do we need to divide things in areas of expertise? Why create silos of domesticated thinking? Can we teach or learn skills and competences one by one? No, our skills and our competences are moored to our tacit knowledge. It takes our whole life to develop and grow this personal knowledge. Areas cannot be silos of action, we need to integrate and interweave them, in ways that let them gain sense, or loose sense. We use them, or we don't. Our lives suffer from circular behaviors and is always pressed towards excesses. We need perspective. We need to understand the environment and how it can affect our projects, we need to be able to discover threats and opportunities in this environment. We need to evaluate the impacts of our action and the impacts of our project and of our project outcomes.

The eight domains named by PMI offer the opportunity for one more, communication. We should consider communication as an organized and articulated set of activities that are critical to the project. Communication calls for specific skills and competences and needs particular and specific focus of our action. Communications need alignment, completeness, background organization, and a constant demand for quality and excellence. Communication also needs specific tools, integrated and systemic tools, information platforms. Communication is a domain that accompanies all life cycle of our projects, develops inside and outside of our projects, exercises formally and informally.

The stakeholder domain, as it is basically the same name of the previous knowledge area, needs a special look. What are our main concerns in this domain? Surely to facilitate the communication with stakeholders, negotiate and debate with them. Requirements are not a result of stakeholders, thy are the output of a negotiation process with the stakeholders. A negotiation of meanings. Negotiation and controversies are our main activities in this domain, trying to stabilize concerns, views and specifications and get all the parts thinking together. This negotiation process needs to be clear, honest and frontal. And, remember value, we should always be envisaging solutions with better value for all. We need all to align, and communication is the grout of this aligning process.

In the team domain, it is essential that, as a starting point, we develop a common view of the problem. The problem should be setup, setting or formulating the problem [25] (Schōn, 1991) should be considered a very important piece of teamwork and is in itself a negotiation process. Only with an internalized common view of the project can we align efforts to attain the right outcomes effectively, in a value perspective.

The planning domain also gains if we are focused in a systemic approach, using critical thinking. The project should always be envisaged as a system in a changing context. Try to define action that is scalable. Actions based on habits you developed by thinking and experimenting, by learning, habits that are effective and protective from mistakes. So, we need to develop habits of effectivity and then train them, internalize them, be sure we use them. If you do things right, if the things you do are effective, you should use them as procedures and scale them up during the project lifecycle. If not, you should stop and revise the way you are acting. Like Edwards Deming once said "Does experience help? No! Not if we are doing the wrong things" [26] (The Deming Institute).

V. Some Clarifications

Please let us all ban "optimization" from our mindset in project management. Optimization is a serious business, but we do not need it to be present in managing projects. What is the real value of proving that your solution is the best of them all (definition of optimization)? is that even possible in a project context? Can you even know how much time you would waste in attempts to optimize? No, in project management we should focus on good solutions, effective and sustainable solutions, not optimal! There is no need, it is not our purpose, except in a very specific kind of project in which optimization is the core itself. In all other project situations we focus on the "as good as possible" under the circumstances [27] (Epstein, 2019).

Revisiting the nine schools of thought in project management [28] (Bredillet, 2008) and [29] Turner et all, 2013), behavioral is the one that is aligned with the flow of our time (the nine schools were governance, behavior, optimization, decision, success criteria, modelling, marketing, contingency, and process). Aligned with a growing complexity of things, of projects and/or project contexts, a shift from an industrial economy to a knowledge economy, the basic and most important aspect in project management is the team member and the team as a whole. The quality and skills of the team, the capacity to understand, reflection abilities, and learning attitude. It is exactly for these same reasons that we need to be flexible and adopt principles, trying to think on processes only after this general alignment, as we have explained. And always investing in the quality of the team. The quality of the project manager and of the whole project team. They cannot be numb executers, they need to be reflective practitioners, Schön (1991) in order to be able to feel

things right, manage their part effectively, be emotionally involved, motivate one another, be available and ready, and always bound in learning.

The team, its values, its reasoning ability, the principles they intuitively follow (constructed intuitions, educated guessing), the way they understand all things as systemic, observing and respecting integration, interdependence and tangling, is the pillar of good project management.

VI. Conclusion

If we were invited to give our say on what is more important in successful project management, we would embark in a short list. And one conviction. That will be our special list.

First of all, problematize, working in group, involving all the team members and the relevant stakeholders. We need to debate and negotiate about what the problem really is. It looks like obvious, but it isn't, many times the problem is hidden, often disguised.

After that we should hear people, everybody. The project team members should be deeply involved with the client and the users. Most of the times the problem is obvious, but often it is not. We, all together, need, with creativity, and guessing, explore conjectures defining the problem. When we arrive at a stable idea of the definition of the problem, we should progress formulating the problem in a clear and effective way. A way that all accept and agree upon. All the team should be aligned in the meaning, and aligned with the relevant stakeholders, all aligned with the purpose of the project. So, first identify, then define, then formulate.

After that, we need to define clearly and deeply our purpose. A first draft of scope should be the result of our effort. A statement of work (SOW) and a project charter are basic collective achievements.

I already mentioned that communication is very, very important. We need to create and define clear rules of communication, where information is: who can update, what are the practices and responsibilities. We need to use a powerful infrastructure that helps us manage all relevant details, having space for short comments and chains of comments. It is very mobilizing to see that our repositories are alive and not something static.

When we think about tailoring, we need to feel that we can create our own space and tricks to manage our projects. Having the main principle in mind we assure a better value performance. We need to understand that the reason why we migrate from areas of knowledge to domains is the systemic view. We should envisage projects as systems and employ our skills and competences integrating the "space" of areas into the domains. Principles and domains are helpful metaphors.

In any learning experience we deal with today we should understand that each one of us learns in his or her own way. We don´t need to systematize too much, each of us can construct the necessary arguments, parallels, images, perceptions. Learning is a total experience, not only a rational approach. Learning involves all senses.

So, a good attitude in project management is to invest in the learning experience of the project. Always try to finish your project knowing much more then at the beginning. If possible do it every day. It is not a principle, it is a challenge.

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Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

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It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

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The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

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Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

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Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

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Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

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6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
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- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
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- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

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Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
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- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
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Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

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Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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