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Front Pages

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The current issue is the first of the eleventh volume of the *Athens Journal of Technology & Engineering (AJTE),* published by the Engineering & Architecture Division of ATINER.

Gregory T. Papanikos, President, ATINER.

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A World Association of Academics and Researchers

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24-27 June 2024, Athens, Greece

The Civil Engineering Unit of ATINER is organizing its **14th Annual International Conference on Civil Engineering, 24-27 June 2024, Athens, Greece** sponsored by the Athens Journal of Technology & Engineering. The aim of the conference is to bring together academics and researchers of all areas of Civil Engineering other related areas. You may participate as stream leader, presenter of one paper, chair of a session or observer. Please submit a proposal using the form available (https://www.atiner.gr/2024/FORM-CIV.doc).

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Important Dates

- Abstract Submission: **5 March 2024**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **27 May 2024**

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- Abstract Submission: **5 March 2024**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **27 May 2024**

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- **Dr. Theodore Trafalis**, Director, Engineering & Architecture Division, ATINER, Professor of Industrial & Systems Engineering and Director, Optimization & Intelligent Systems Laboratory, The University of Oklahoma, USA.

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Study on the Stresses Released in a Notched, Postensioned Concrete Beam

By Juan A. Mateu-Sánchez[*], Ester Giménez-Carbó[±], Pedro Serna[°], Carmen Castro-Bugallo[•], Juan Navarro-Gregori[♦] & Jose R. Martí-Vargas[♥]

Structural prestressed concrete elements (SPCE) face uncertainties in accurately assessing the actual prestressing force. Over time, the initial prestressing force decreases due to several factors. Incorrect estimation of prestress losses can lead to design inefficiencies or structural issues. Monitoring the prestressing force can be achieved through instrumentation during casting, but existing SPCE lack such devices, necessitating indirect methods to determine prestressing force variations. This study focuses on analyzing stresses released in a notched post-tensioned concrete beam using the saw-cutting technique. Surface notches induce local decompression, allowing for strain measurements in the isolated concrete block. These measurements, considering uncertainties in initial prestress and material properties, are analyzed through backward calculations. The findings enhance understanding of saw-cutting and enable future applications to determine effective prestressing force in unmonitored SPCE. Further experimental studies are required to explore prestressing force consistency under monitored conditions. This research provides valuable insights into the potential of the saw-cutting technique as a non-destructive testing method for assessing prestressing force in unmonitored SPCE. Accurately determining the prestressing force is crucial for evaluating existing SPCE and ensuring their structural integrity.

Keywords: *prestressed concrete, beam, test, saw-cut, notch*

Introduction

Much of the existing bridges in Europe and the United States, made of structural prestressed concrete elements (SPCE), date back to the 1950s and 1960s and are approaching the end of their service life, regardless of the prestressing technique used (post-tensioning or pretensioning) (FIB 2016). This raises concerns about the condition of these elements and how they affect the overall behavior of the structure. Most SPCE that are nearing the end of their service life were built using outdated codes and regulations that did not consider the deferred effects of

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concrete and steel with the same importance as they are considered today. The lack of consideration for the magnitude of deferred effects and consequently the state of stress in the structure, combined with the different loading conditions than those anticipated in the design, as well as premature degradation of SPCE, result in a state of stress uncertainty that needs to be addressed immediately.

In the case of prestressed concrete using prestressed steel reinforcement, specifically in post-tensioned concrete elements, the prestressing force experiences a decrease over time due to factors that occur instantaneously and others that are time-dependent. Instantaneous factors include prestress losses caused by friction between steel and concrete, elastic shrinkage of concrete, and loss of fit in the anchorage device. On the other hand, time-dependent factors include creep and shrinkage of concrete, as well as relaxation of the reinforcement steel.

As a result, the peculiarity of prestressed concrete structures becomes highly relevant, as their behavior in terms of tension and deformation depends not only on external loads but especially on the interaction between concrete and active steel that generates prestress. According to Professor Calavera, prestress losses over time represent a complex phenomenon in which the reinforcement is anchored in fluid concrete subjected to progressively decreasing tension (Calavera 2018). Professor Nawy, on the other hand, maintains that it is impossible to accurately determine the magnitude of these losses, especially time-dependent ones, due to the multiplicity of interrelated factors. Different practice codes use empirical methods to estimate such losses, but there are variations among them (Nawy 2005).

For this reason, there is a need to determine the level of prestress acting on the structure to assess the condition of a SPCE, as the influence of prestress on these types of structures is essential and needs to be evaluated to prevent premature aging, excessive deflections, and the occurrence of unexpected cracks. The design of such elements is truly complex since the designer must determine the prestress and estimate the prestress loss so that the structure meets its required performance during its service life, which is particularly challenging when considering deferred effects whose influence has been proven to be significant in the long-term durability of the structure.

Traditionally, periodic visual inspection practices dominate maintenance programs worldwide (Li et al. 2016). However, it is true that these visual inspections are insufficient to meet the current maintenance needs, especially in prestressed concrete structures where damage can often remain hidden due to the compressive effect caused by prestress (Kim et al. 2011, Lynch 2007). Due to the cases of premature aging in SPCE, there is a need to explore new techniques to determine the acting prestress in the structure, aiming to verify if indirect estimation techniques, based on displacements, can predict the prestress force.

Recent studies (Azizinamini et al. 1996, Halsey and Miller 1996), conducted on existing prestressed concrete elements have reported difficulties in determining prestress losses and residual prestress force. Many PCMs were built without proper instrumentation, making it challenging to directly estimate the residual prestress force. In such cases, additional complex factors need to be considered, such as initial prestress, material properties and their evolution, as well as short-

term and long-term prestress losses. These difficulties are associated with assumptions about the characteristics of the prestressing system, time-dependent phenomena, and potential degradation processes. In some instances, uncertainties related to prestressing have led to the collapse of prestressed concrete bridges.

Therefore, according to the Strategic Plan 2020-2023 of the World Road Association - PIARC (2020), it is necessary to promote the use of scientific methods and state of the art techniques in the evaluation of existing structures. This is crucial to address the uncertainties associated with prestressing and ensure the safety and reliability of prestressed concrete structures in service.

In this paper, a study and application of the saw-cut technique for a prestressed concrete beam under controlled laboratory conditions are proposed, in which the results will be analyzed and verified using a finite element model.

To achieve this, the following methodology is proposed, which will present different techniques for obtaining prestress, the selection and justification of the technique used in this study, the properties of both the materials and the beam geometry will be discussed, as well as the instrumentation selected for measurement, arrangement, and the results obtained in the test will be discussed.

Techniques for Obtaining Residual Prestress

The techniques that can be used to obtain residual prestress in prestressed concrete elements (SPCEs) can be divided into two main groups. The first group is called direct methods, which involve continuous monitoring techniques through the inclusion of measurement sensors during the execution of SPCEs.

Within the direct methods, there are two main categories based on the actions on the prestressing tendon. The first category involves measuring the tension in the tendon using techniques such as strain gauges or fiber optic sensors. The second category involves sensors that provide the prestressing force, such as force transducers, electromagnetic sensors, ultrasonics, and others.

Another classification can be made based on measurements on the concrete itself. In this case, displacement measurements on the concrete are used to obtain internal stress-displacement relationships. Techniques such as vibrating wire strain gauges (VWDG) and vibrating beam strain gauges (VBSG) are used for this purpose. Surface displacement measurements can also be obtained using devices in contact with the concrete surface, such as strain gauges or mechanical measurement techniques at localized points. Non-contact techniques like photogrammetry, interferometric laser, scanner, or stripes.

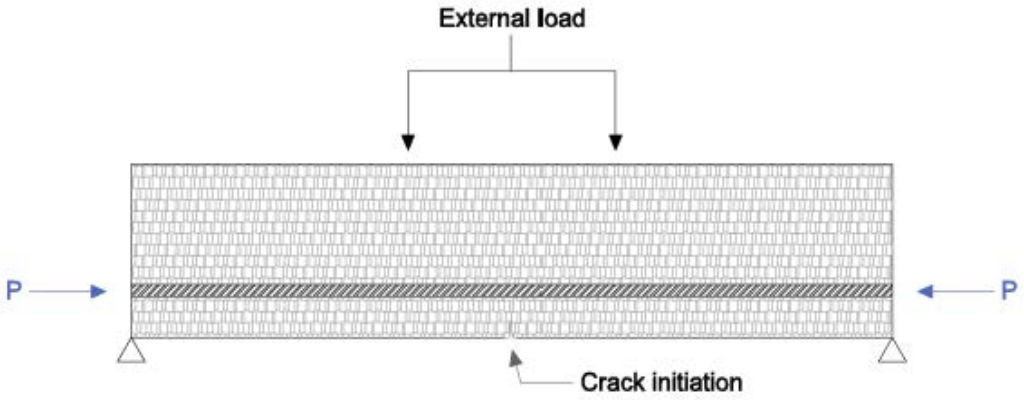
All the above mentioned techniques do not affect SPCEs. However, unfortunately, continuous monitoring sensors are relatively recent techniques and SPCEs nearing the end of their service life, which require more information about their stress state, may not have these continuous monitoring devices available.

There are numerous methods available to obtain the stress state of older structures where information about the evolution of prestress is lacking. These indirect measurement techniques have been developed over time through real-

scale testing. They can be classified based on their impact on the structure into two main groups: destructive and non-destructive methods.

Destructive methods are the most studied and commonly used in practice, especially for structures that have been dismantled and will not be put back into service. Non-destructive methods, on the other hand, are more specific and offer great potential for evaluating SPCEs in service. They are less destructive techniques for obtaining the stress state.

Figure 1. *Scheme Flexural Crack*



The following are the different indirect methods, both destructive and non-destructive, which demonstrate the testing scheme of each method. One type of method is the Loading Test, which has two main variants based on different applied stress states in the beam. In the first variant, as shown in Figure 1, an SPCE is subjected to a bending moment in a frame where the main objective is to apply a load that generates only normal stresses in the concrete. The load is increased until the first crack appears, resulting in a zero stress on the bottom surface of the beam. Using stress-strain relationships, the applied flexural force can be used to determine the prestressing force acting on the beam. This method has been widely used over time, resulting in a wide range of results. However, its main drawback is the need for laboratory testing and the significant damage inflicted on the beam, including decompression and the formation of cracks that can lead to corrosion and degradation of the steel if the SPCE is put back into service, making it impractical for inspection (Azizinamini et al. 1996, Halsey and Miller 1996, Riessauw and Taerwe 1980, Tabatabai and Dickson 1993, Pessiki et al. 1996, Labia et al. 1997, Naito et al. 2008, Osborn et al. 2012, Pape and Melchers 2013, Botte et al. 2021, Yuan et al. 2015).

Figure 2. *Scheme Crack Re-openning*

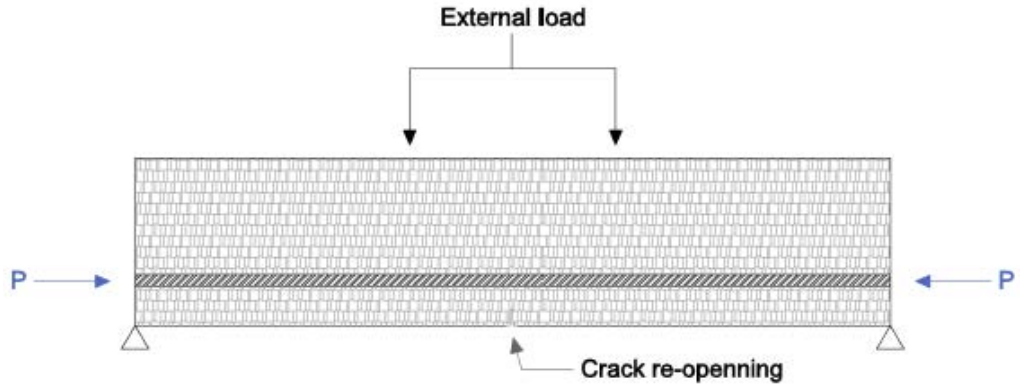
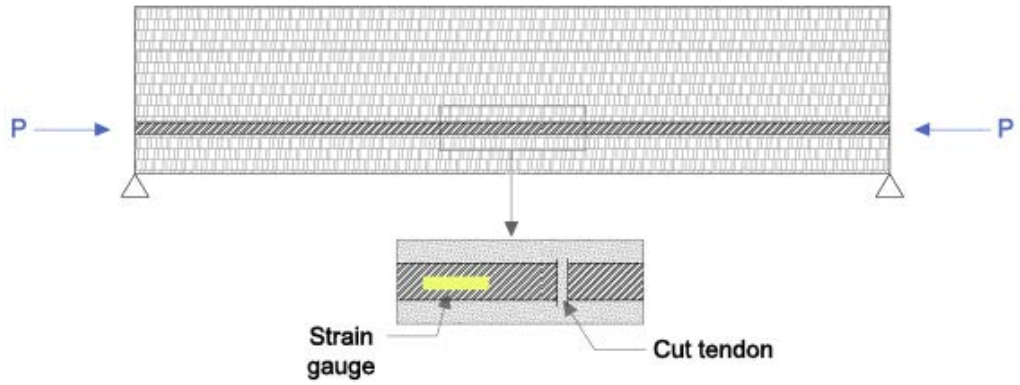


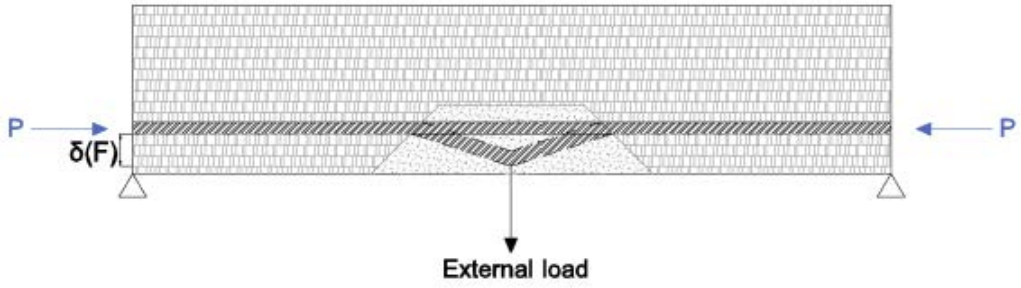
Figure 2 illustrates a method based on the same methodology as the previously discussed technique. In this technique, an applied force causes crack opening, and successive load increments induce the opening of the crack. The crack closure capacity is then analyzed, hence its name crack reopening. This method starts from an initially pre-cracked state. For a long time, this method has been used to analyze beams that have been taken out of service to examine their actual condition and observe the residual prestress in SPCEs.

Figure 3. *Scheme Tendon Cutting*



As for the method applied directly to the prestressing cable, two methods are found. The first one is the strand cutting method, where a complete cut is made in the prestressing tendon to observe the deformation released after the cut. Instrumentation is done by placing a strain gauge on the steel, followed by a total cut of the prestressing tendon, as shown in Figure 3. The main drawback of this method is the need to excavate the area around the cable to install the strain gauge, and it renders the SPCE completely unusable as the effect of prestressing is eliminated. This technique has not been extensively used due to the significant number of disadvantages it presents.

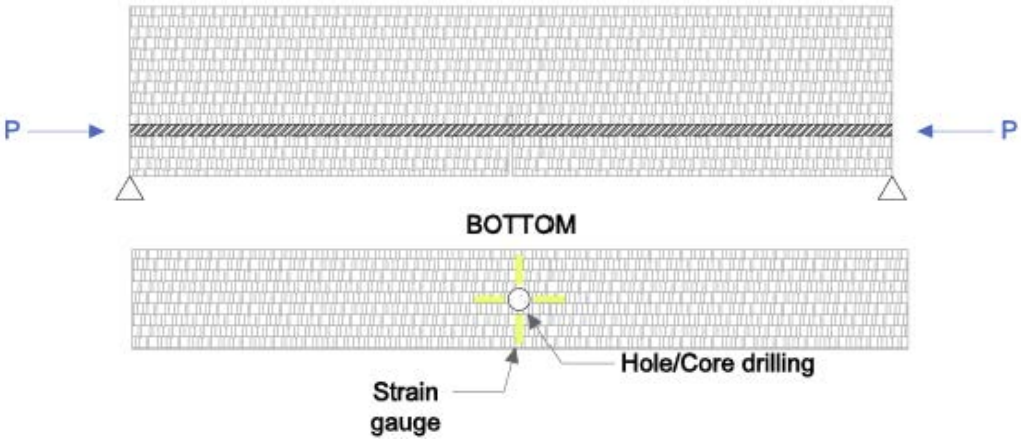
Figure 4. *Scheme Strand Tendon*



Another technique based on direct actions on the steel is the exposed tendon method. It follows a similar procedure to the previous method, but instead of cutting the tendon, a force is applied perpendicular to the cable. The tension state can be determined based on the displacement that occurs in the cable. It is not clear whether this technique can be considered non-destructive since accessing the prestressing tendon requires removing a significant volume of concrete, which can affect the functional capacity of the beam, as shown in Figure 4.

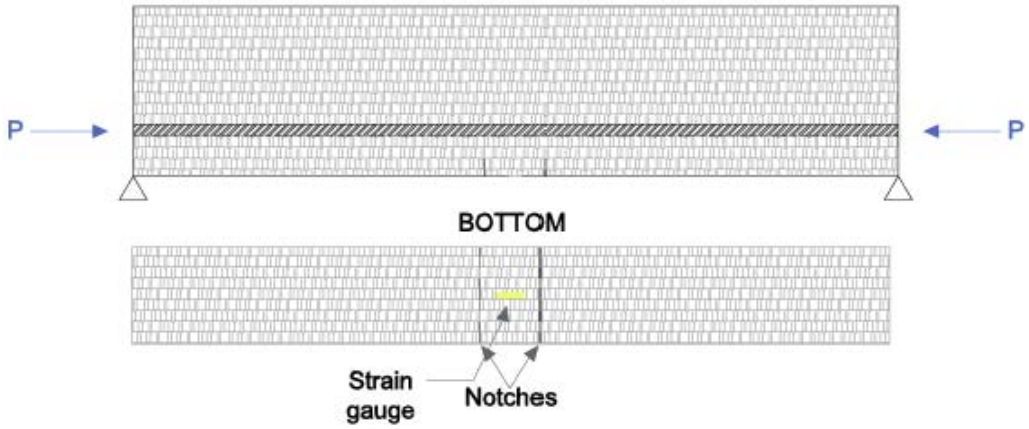
Lastly, regarding the different techniques for determining residual prestress in SPCEs, techniques based on actions in the concrete stand out. These techniques have been the most widely used in recent years, but there is still a considerable level of uncertainty and parameters that have not been fully controlled yet.

Figure 5. *Scheme Hole/Core Drilling*



One notable technique is the Hole/Core-Drilling technique, which involves drilling a hole in the concrete using either a drill bit or a core bit, depending on the diameter. It is a simple technique with a straightforward application for measurement. However, according to different studies, it presents high uncertainties due to the unclear path of forces, resulting in significant uncertainty (Kesavan et al. 2005, Parivallal et al. 2011). Figure 5 shows a possible arrangement for performing this reverse measurement technique of the prestressing force using strain gauges. It is a technique that can be easily restored, allowing the element to be put back into service after minor repairs.

Figure 6. *Scheme Saw-Cut*



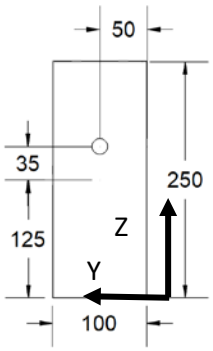
Finally, a technique that has emerged in recent years is the saw-cutting method, which involves creating notches in the concrete. This technique primarily isolates a block of concrete by making cuts in the concrete. This isolation allows measurements of deformations without the interference of prestressing. Various studies (Kralovanec et al. 2021, 2022a, b) demonstrate that by placing a strain gauge in the middle of the isolated block, it is possible to measure the deformation as the notch depth increases. This arrangement can be seen in Figure 6. Therefore, considering the aforementioned information, the apparent conceptual simplicity of the Isolated Concrete Block Method or saw-cutting method (ICBM), along with its low impact on the structure (the cuts only affect the concrete layer and can be resealed) (Bauset-Tortonda et al. 2023), instill confidence in overcoming the limitations associated with the hole-drilling technique (low stress release, instrumentation difficulty, etc.). Thus, the ICBM has clear potential to become a practical, economical, and reliable non-destructive method for assessing SPCEs.

Methodology

Geometry

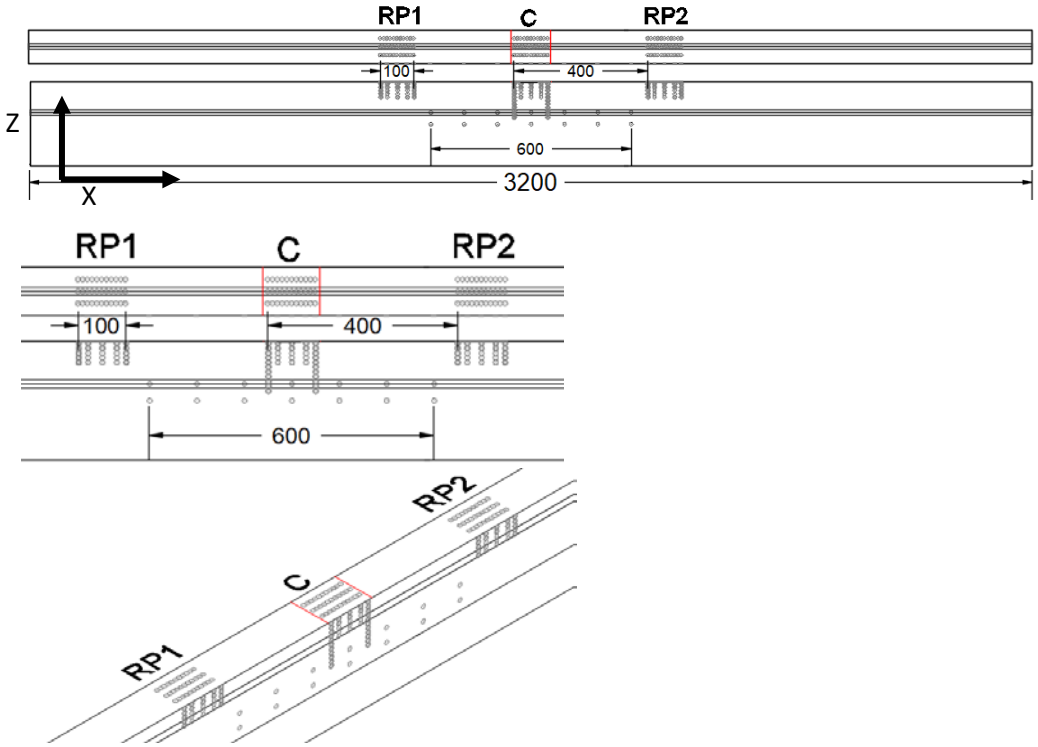
The experimental specimen is a prestressed concrete element with a total length of 3.20 meters. The free length between supports is 3 meters, which means there is a 20 centimeter space at each end that is not subject to support restrictions. This configuration allows for the analysis of the element's behavior under specific loading and deformation conditions. Regarding the height at which the prestressing cable is placed, it has a straight path and an eccentricity of 0.035 meters with respect to the center of gravity of the concrete gross section.

Figure 7. *Cross Section*



The cross-sectional shape of the specimen has a depth of 0.25 meters and a width of 0.10 meters (see Figure 7). This rectangular cross-section provides an adequate contact surface for prestressing and ensures the strength and stability of the element. Additionally, the size of the cross-section is designed to meet specific design requirements and ensure a sufficient stress concentration capacity due to prestressing to eliminate the Splitting effect. To achieve this, steel distribution plates with a depth of 0.25 meters and a width of 0.10 meters are used. These plates are placed at the ends to efficiently distribute and transmit the prestressing forces. The use of steel distribution plates allows for the application of a uniform and controlled prestressing force to the element. Figure 8 shows the characteristics of the cross-section, as well as the longitudinal view.

Figure 8. *Top and Front View*



The experimental specimen has been designed and constructed for testing the isolated block method and conducting a detailed analysis of its structural behavior after the notches are made.

Prototype Execution

For the execution of the prototype, metal formwork panels were used, placed on a flat and leveled surface. The formwork panel measured ninety centimeters in width and three meters in length. To achieve a total length of 3.20 meters, an additional formwork panel was placed at a 90-degree angle, resulting in a total formwork length of 3.90 meters, allowing for the production of 3.20-meter beams.

During the execution of the shown beam, the formwork was also used to create two additional constituent beams using the same material. For this purpose, wooden beams were placed along the entire length of the beam, and two cross beams were used to ensure the horizontal alignment of the cable duct. To achieve this, three corrugated steel bars were inserted inside the ducts to ensure parallelism with the longitudinal faces. Alongside the beams, 14 cylindrical control specimens were used to monitor the material properties, compacting them in thirds using 25 blows, as stated in the EC2 standard for concrete control and execution. Figure 9 shows the procedure and pouring of the control specimens.

Figure 9. *Specimen Running Process*

Materials

The concrete used for the execution of the SPCEs in question had certain necessary characteristics to achieve a minimum strength of 27 MPa at 48 hours to allow for transportation and avoid cracking issues. The dosages employed are shown in Tables 1 and 2.

Table 1. *Dosage for Concrete*

Material	**Weight (kg/m^3)**
Gravel 8/16	690 kg
Gravel 4/8	290 kg
Red Sand	820 kg
White Sand	74 kg
Cement	450 kg
Water	180 kg
Additive	6 kg

Table 2. *Material Properties*

Material	Aparent density (kg/m^3)	Dry density (kg/m^3)	Sat density (kg/m^3)
Gravel 8/16	2.76	2.69	2.71
Gravel 4/8	2.76	2.69	2.71
Red Sand	2.74	2.67	2.69
White Sand	2.52	2.46	2.48

Regarding the cement used, it is a type CEM I 42.5 R-SR5 suitable for protection in marine environments, high-strength concrete, and sulfate resistance.

Figure 10. *Abrams Cone and Placement in the Concrete Formwork*

Regarding the manufactured concrete, a fluid concrete was obtained during its execution, corresponding to an Abrams cone value of 25 cm, as shown in Figure 10. Additionally, this fluid concrete facilitated its placement and filling in the formwork, resulting in a more homogeneous surface that will facilitate the instrumentation.

Instrumentation

For the instrumentation of the beam, an effective and user-friendly mechanical method called DEMEC was chosen.

DEMEC (Demountable Mechanical Strain Gauge) is a useful tool that offers several advantages compared to surface-mounted electrical resistance strain gauges for concrete. Here are some reasons why DEMEC is a preferred option:

Precision and reliability: DEMEC allows for precise and reliable deformation measurements. With precision manufacturing and careful use, high measurement accuracy can be achieved at different points of a structure. This is especially important in civil engineering and construction applications where accuracy is crucial for assessing structural integrity and safety.

Cost-effectiveness: DEMEC provides a cost-effective alternative to electrical strain gauges. It does not require complex electrical equipment or complicated installation. Moreover, being a reusable instrument, it can be used for multiple measurements, reducing long-term costs.

Ease of use: DEMEC is user-friendly and does not require specialized technical knowledge. With proper practice, quick and accurate measurements can be made. Additionally, the instrument comes with reference and adjustment bars, further facilitating its implementation.

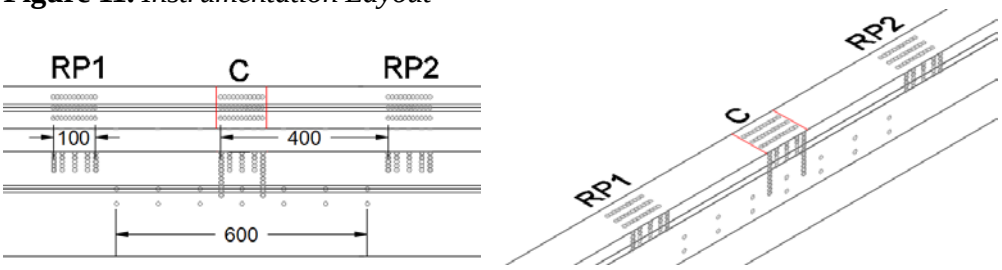
Adaptability to different materials and structures: Unlike electrical strain gauges that primarily focus on the concrete surface, DEMEC can be used on a wide range of materials and structures. Whether it is concrete, steel, or other structural materials, DEMEC can be adapted to different applications and environments.

Elimination of thermal effects: DEMEC is designed with thermal effects in mind. It uses an Invar reference bar, a metal with a very low coefficient of thermal expansion, which helps eliminate the effects of temperature changes on measurements. Furthermore, if significant temperature changes are expected in the concrete during testing, a simulated concrete bar can be used to eliminate thermal effects on the instrument.

After conducting previous prototypes prior to this specimen, a comparison was made between strain gauges that measure deformation through electrical resistance and mechanical strain gauges. It was observed that the mechanical strain gauges exhibit lower sensitivity to thermal variation compared to the electrical resistance ones. When radial cuts were made near the strain gauge location, the measurements of the mechanical strain gauges were affected due to the temperature increase during the cutting process. These factors have been addressed in other research works (Kralovanec et al. 2021), which discuss potential issues related to temperature variations during sawing and their impact on measurements. Finally, Figure 11 shows the instrumentation plans, with the RP1 zone indicating the beam's center.

The measurement instruments used for the test were a DEMEC device with a 100mm arm and another DEMEC device with a 400mm arm. By using these devices, measurements could be taken from a location far enough from the cutting zones to avoid interference or displacements that could affect the measurements.

Figure 11. *Instrumentation Layout*



A total of 200 DEMECs were installed. On the top face, three rows of DEMECs were placed at one-centimeter intervals, positioned at heights of Y=25 mm, Y= 50mm, and Y=75mm from the top face. The same arrangement was made for RP1, located at 400mm, and for C, equidistant in the opposite direction from RP2, also at 400mm from RP1. These DEMECs were responsible for measuring the deformation on the top face.

Regarding the lateral faces of the beam, four measurement zones were established. One zone was located at the chord corresponding to the center of gravity of the beam's cross-section (Z=125mm), with 7 DEMECs placed 100mm apart from each other, providing a total control length of 600mm in that zone.

Similarly, another zone was placed at the cable height (Z=160mm), creating two measurement zones to monitor deformation at the beam's central points. Additionally, in order to assess stress concentration once the notches were made at the two cutting points, different measurement points were placed in the central zone to observe displacements at the notch edge as the distance to the cut increased.

Materials Properties

The concrete used for the previously explained specimen had an average compressive strength of 41.66 MPa at 48 hours, obtained from the rupture of three cylindrical specimens. The modulus of elasticity was determined to be 34,645 MPa. On the test day, which was 7 days after execution, the compressive strength values of the specimens were 51 MPa, 52 MPa, and 53 MPa, while the modulus of elasticity of the concrete at 7 days was determined to be 36,579 MPa.

Regarding the steel used for the active reinforcement, it was Y1860 S7 steel with a diameter of 13mm, and the manufacturer provided a modulus of elasticity of 195,000 MPa.

Materials used to Measure

The various devices used to perform the test under controlled conditions are discussed below:

Hydraulic jack: The jack used for tensioning corresponded to a mono-strand jack with load regulation through a manual hydraulic circuit, as shown in Figure 12.

Figure 12. *Hydraulic Jack for Prestress*

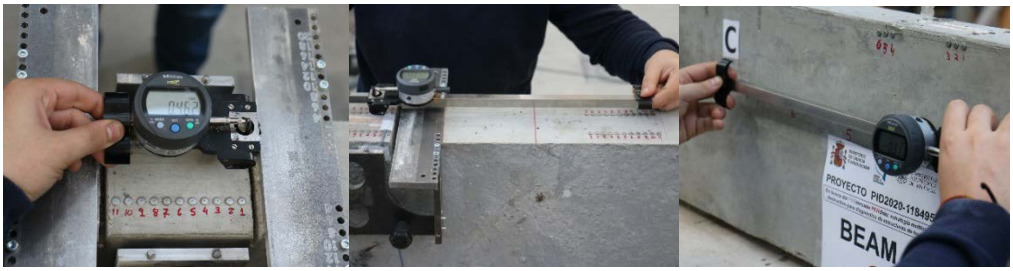
To measure the forces during tensioning, cutting, and detensioning of the beam, a force transducer with amplifier tracking was employed. For proper cutting, a cutting tool specifically designed for the occasion was used, which was adaptable to elements of different widths and modular to allow measurements without removing it. A diamond-tipped angle grinder with adjustable disc width and height was used for the cutting process, with the maximum depth reaching 60mm. However, considering that the supporting tool is elevated by a total of 10mm, the actual maximum depth in the SPCE was 50mm. Finally, Figure 13

shows the different elements that facilitated the test at all times, both for measurements and functionality.

Figure 13. *Devices Used for the Test*

Two high-precision devices, DEMECs, were used to measure deformations. Two different devices were employed for this occasion, one with a measuring base of 400mm and the other with 100mm. The measurement procedure with these devices, which are highly sensitive to deformations generated in the concrete, is based on a differential measurement approach. An initial measurement, or zeroing, is performed, and then deformations that occur after making the notches are measured based on the differences. Figure 14 illustrates the measurement process.

Figure 14. *Measurements using DEMECs, Measurement base 100 and 400 MILLimeters*



Test Sequence

The specific test presented in this article followed the following work program:

1. Placement of the beam at the test site.
2. Initial measurements taken.
3. Placement of the cable and distribution plates at the ends of the beam.
4. Installation of the force transducer and anchoring wedges for prestressing.
5. Tensioning of the prestressing cable up to 150 kN, followed by wedging of the jack (126.8 kN).

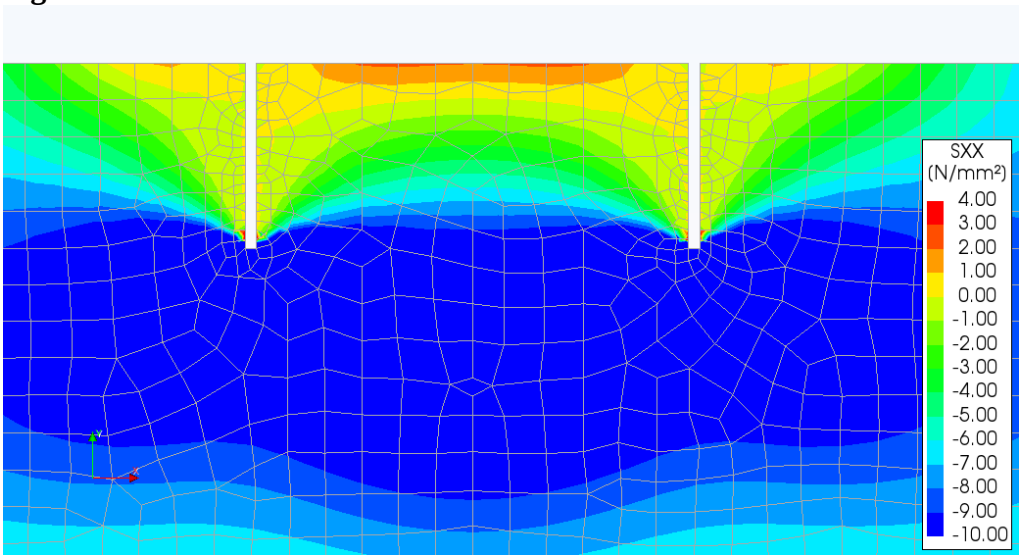
6. Once the cable force has stabilized, measurements are taken to determine the deformations after beam prestressing, accounting for losses due to wedge penetration.
7. Implementation of the cutting sequence: The execution of the test involves complete cuts of the block, which are performed based on two notches spaced 12mm apart. These notches are made in opposite directions, following the same methodology for each depth. The methodology remains consistent throughout the cutting process. After making the two notches corresponding to a complete cut, measurements are taken for all points. Initially, measurements are taken using the 400mm base DEMEC device from points RP1 to C and from C to RP2 on the top face (Z= 250mm). The purpose is to obtain deformations within the isolated block with respect to external reference points. After these measurements, measurements are taken on the lateral faces of the beams, specifically on the chord located at the center of gravity and the one located at the cable height, as well as measurement points from RP1 to C and from C to RP2 on the lateral faces. After obtaining all measurements from the 400mm base DEMEC, corresponding measurements are taken using the 100mm base DEMEC. This allows us to observe the behavior between closer points. Similarly to the 400mm base measurements, initial measurements are taken on the top face of the SPCE (Z=250mm), followed by measurements on the lateral face (Y=0). This entire sequence is performed for each of the cuts made, with depths of 5mm, 15mm, 25mm, 30mm, 35mm, 40mm, and 50mm in the concrete section.
8. After completing all the aforementioned measurements, the detensioning of the beam is carried out to allow for future tests and to evaluate the recovery capacity of the tested beam after the test.

Figure 15. *SPCE in its Final State Before Detensioning*

Numerical Model

In order to evaluate the different results, a finite element model was created using the DIANA software based on a previous study (Bauset-Tortonda et al. 2023). The model parameters were modified to capture the behavior of the beam and align it with the experimental results. Figure 16 shows the implemented model and the stress state of the prestressed concrete at the end of the test.

Figure 16. *DIANA Numerical Model*



All the analysis model data were adjusted to match the tested specimen in order to verify and test the model for future studies.

Results

The following are the results obtained from the data analysis. First, the variations in displacements relative to the central point of the isolated block are shown for each of the depths at which the cuts were made, as shown in Figure 17.

Figure 17. *Average Displacement Variation in Z=250 mm*

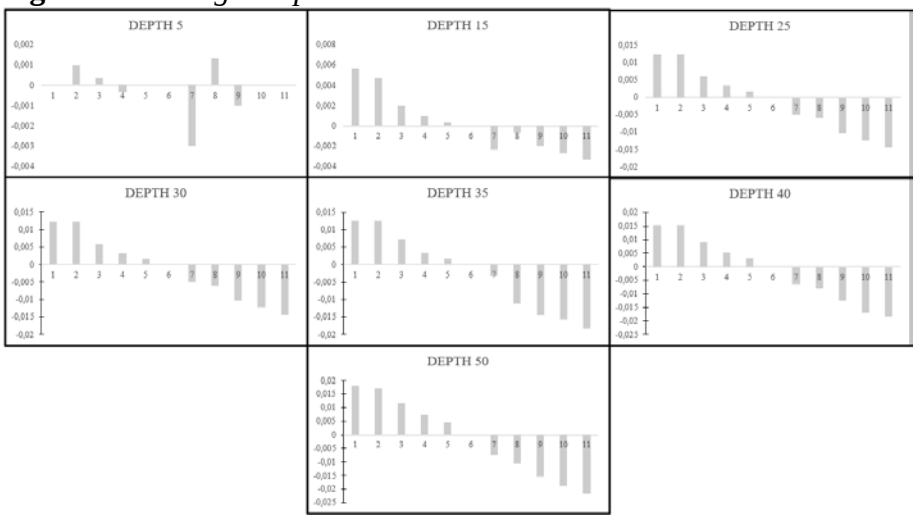
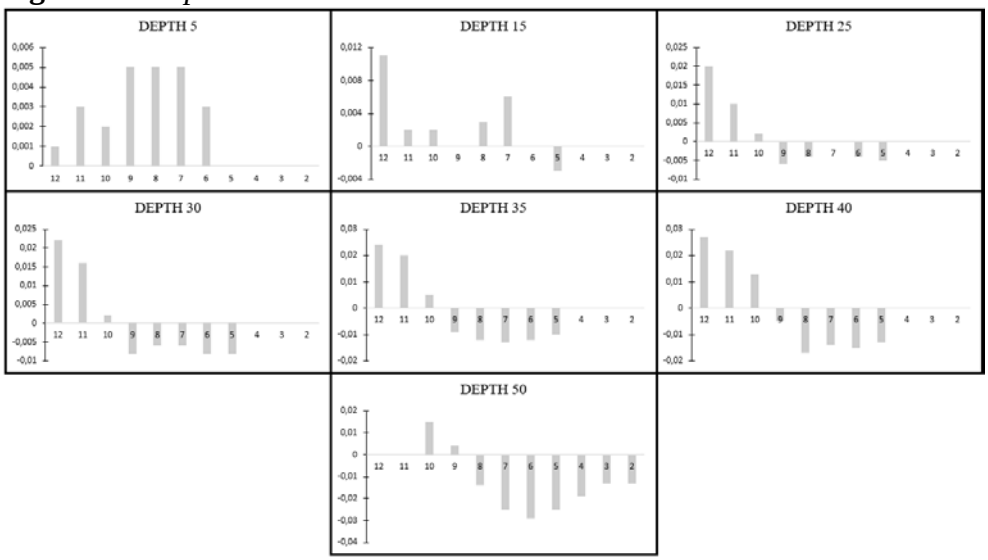


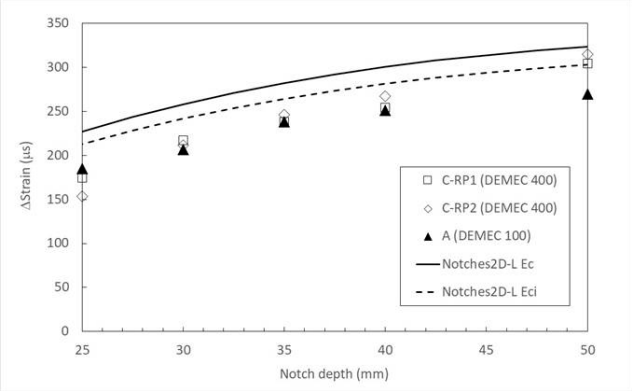
Figure 18 represents the displacement variations relative to prestressing on the lateral faces of the specimen and their evolution as the depth of the cut increases. It is important to note that measurements for points 4, 3, and 2 could not be taken due to their inoperability caused by the cutting tool. Additionally, in the 50 mm cut, references for points 12 and 11 were lost, resulting in the inability to obtain measurements for those points.

Figure 18. *Displacement Variation in Y=0 mm*



Finally, the results obtained during the experimental test are shown in Figure 19, which represents the averages of the measurements taken on the upper face (Z=250mm) from the reference point RP1 and C, as well as those from C and RP2, and the internal variation between the outermost points of the isolated block C. The graph displays the displacement variations from the prestressing operation at each of the selected depths, as well as the results obtained from the numerical modeling represented by the names Notches2D-L Ec and Notches2D-L Eci. The former uses the secant modulus, while the latter uses the tangent modulus for the corresponding elastic modulus.

Figure 19. *Representation of the Displacement Variation as a Function of the Depth of Notch*



Discussion

Regarding the analysis of the results at the isolated block level, there is a significant dispersion in the results obtained for shallow depths, particularly at a depth of 5 mm. As the depth increases on the upper face (Z=250mm), there appears to be an increase in the displacement of each point as we approach the notches, indicating a complete release of stresses in those nearby points. Furthermore, as the depth increases, the variation in displacement with respect to the central point also increases, as shown in Figure 17.

Regarding the displacements obtained on the lateral faces, as observed in the figure, an upper fiber decompression occurs as the notch depth increases. This means that as the notch depth increases, the upper fibers decompress, while the immediately following fibers experience greater compression, as observed in Figure 18. However, similar to the upper face, the results obtained from the tested beam exhibit values with significant dispersion.

In relation to the values obtained for the cutting point (C) and the external reference points (RP1 and RP2), it can be observed that the displacement values obtained from the 400 mm measurement base from an external reference point and the variability between the values obtained from the internal points using the 100 mm measurement base coincide. This suggests that the reference points remain unchanged at a distance of 400 mm.

Although the values obtained from the numerical model show a similar trend in the behavior of the beam, a slight deviation is observed between the curve obtained from the experimental specimen and the numerical model. After conducting a thorough analysis, it was concluded that the elastic modulus of the concrete could be more similar to the tangent modulus than the secant modulus of the concrete. Therefore, a modification was made to the model by adjusting the modulus to correspond to the tangent modulus, as the concrete is undergoing a process of unloading. The Notches 2D-L Eci model was adjusted according to the specifications outlined in the Model Code 2010 (FIB 2010), resulting in a closer approximation to the experimental curve and improving the accuracy of the model.

Conclusions

The execution of an experimental test and the implementation of a numerical model have allowed for the study of the effect of induced notches on prestressed concrete elements. This study is essential to support the evaluation of residual prestressing force using the non-destructive and indirect methodology known as saw cutting.

From this study, the following conclusions have been drawn:

1. There is a significant dispersion in the results obtained for shallow depths, particularly at a depth of 5 mm.

2. As the depth increases on the upper face, there is an increase in the displacement of each point near the notches, indicating a complete release of stresses at those points.
3. Increasing the notch depth on the lateral faces leads to decompression of the upper fibers and increased compression in the immediately following fibers.
4. The results obtained from the tested beam exhibit values with significant dispersion on both the upper face and lateral faces.
5. The displacement values obtained from the 400 mm measurement base from an external reference point and those obtained between the internal points using the 100 mm measurement base coincide.
6. The reference points remain unchanged at a distance of 400 mm.
7. There is a slight deviation between the curve obtained from the experimental specimen and the numerical model.
8. The elastic modulus of the concrete could be more similar to the tangent modulus than the secant modulus of the concrete.
9. Adjusting the modulus to correspond to the tangent modulus in the numerical model improves accuracy and provides a closer approximation to the experimental curve.

Finally, it is important to mention that this measurement methodology reduces the influence of thermal variation caused by the temperature increase generated by saw cuts. Additionally, it would be interesting to further investigate the nonlinearity of concrete under fiber decompression circumstances in order to calibrate the model more accurately to reality and validate the model.

Acknowledgments

This work forms part of the Project “Looking for the lost prestress: multi-level strategy and non-destructive method for diagnosis of existing concrete structures” funded by the Agencia Estatal de Investigación (State Research Agency) of Spain (competitive research project PID2020-118495RB-I00 / AEI / 10.13039/501100011033 and human resources funding PRE2021-098777 / AEI / 10.13039/501100011033). The authors would also like to thank the ICITECH technical staff, Francisco J. Martorell Romero and Daniel Tasquer Val, for their valuable contributions and involvement in the development of the experimental work.

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Predicting Stock Prices Using Deep Learning Algorithms: A Case of Food-Processing Industry

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Prediction of stock prices has been a focal point of the financial body of knowledge for decades now. The complexity of stock price prediction involves various factors, including market trends, economic indicators, company performance, news sentiment, and more. Accordingly, stock prices are said to follow the 'random walk hypothesis'. This systemic factor should be coupled with the limited human cognitive abilities to envisage the dynamics of financial markets. Novel machine learning algorithms have been advocated as potentially supreme replacement for the 'human-centric' stock prediction approaches. Hitherto, a myriad of machine learning algorithms has been effectively used for this purpose – ARIMA (Auto-Regressive Integrated Moving Average), XGBoost (Random Forest and Gradient Boosting Algorithms), CNN (Convolutional Neural Networks) or LSTM (Long Short-Term Memory). The aim of this paper is to test the predictive capacity of LSTM on a sample of large global food industry companies. The prices of shares of five companies were observed, namely: PEP (PepsiCo), TSN (Tyson Foods), NSRGY (Nestle), JBSAY (JBS S.A.), KHC (The Kraft Heinz Company), in the period from 01.01.2015. until 1.11.2022. Based on the data from this time range, a stock price forecast for Nov 2nd, 2022, was made. The results indicate very precise prediction since the difference between predicted and real stock price is insignificant.

Keywords: *stock price, machine learning, long-short term memory, food-processing industry*

Introduction

Prediction of stock prices has been a "holy grail" of financial management for many decades now. Accurate prediction of changes in price can reduce the risk and improve returns (Lu et al. 2020). The complexity of stock price prediction involves various factors, including market trends, economic indicators, company performance, news sentiment, and more (Shaban and Al-Zubi 2014). Accordingly, stock prices are said to follow the 'random walk hypothesis' and their price prediction is hard, if not impossible. This systemic factor should also be coupled with the limited human cognitive abilities to envisage the dynamics of financial markets.

Nowadays, machine learning has been applied to stock price prediction by utilizing historical stock market data to train models that can forecast future stock prices. These algorithms have been advocated as potentially supreme replacement

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for the 'human-centric' stock prediction approaches. Hitherto, a myriad of machine learning algorithms has been effectively used for this purpose – ARIMA (Auto-Regressive Integrated Moving Average), XGBoost (Random Forest and Gradient Boosting Algorithms), CNN (Convolutional Neural Networks) or LSTM (Long Short-Term Memory). The latest one is particularly suitable for capturing patterns in time series data, making them suitable for stock price prediction. LSTM networks consist of memory cells that store state information over time using memory and output units that regulate and control the flow of information through them. These networks use three types of gates - forget, input and output. Since LSTM networks can assign different weights to input variables it automatically selects the most relevant variables. Hence the ability of LSTM to capture the long-term dependence of time series and the ability to forecast financial time series. However, the disadvantage of the LSTM algorithm is that it takes a long time to train and requires a large sample of data.

Having this in mind, the aim of this paper is to test the predictive capacity of LSTM on a sample of large global food industry companies. The prices of shares of five companies were observed: PEP (PepsiCo), TSN (Tyson Foods), NSRGY (Nestle), JBSAY (JBS S.A.), KHC (The Kraft Heinz Company), in the period from 01.01.2015. until 1.11.2022. Based on the data from this time range, a stock price forecast for Nov 2nd, 2022, was made.

To the best of authors' knowledge, a study of this kind has never been conducted before. LSTM has been widely used for stock price predictions (see Selvin et al. 2017, Jin et al. 2020, Mehtab et al. 2021). However, the food processing industry has not been analyzed as a case study. Scarce evidence can only be found for the pet food industry (see Ahnaf et al. 2021).

The remainder of the study is organized as follows. Section 2 provides a theoretical background of the study, putting the general emphasis on the predictability of stock prices. Section 3 explains the LSTM as a general approach used in this study to predict the stock prices on the selected group of companies from the food processing industry. Section 4 elaborates on the main findings and results of the study. Section 5 contextualizes the findings by explaining the implications, contributions, limitations and further recommendations. The last part of this section is reserved for the concluding remarks.

Theoretical Background

In this section, we explain the theoretical concept behind the predictability of any class of investments through the Random Walk Hypothesis. After that, we consider how deep learning (a class of machine learning algorithms) can be used to forecast stock prices.

Random Walk Hypothesis

The financial industry has always been interested in successfully forecasting financial time series. Numerous studies have been published on machine learning

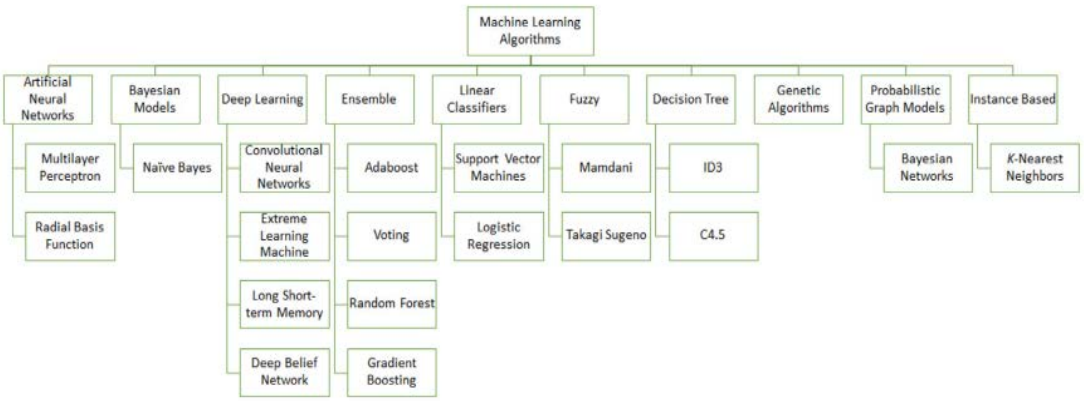
models with relatively reliable performances. Meanwhile the widespread adoption of automated electronic trading systems along with the increasing demand for higher returns continues to compel researchers and practitioners to work on the implementation of better models.

Nonetheless, financial theory has not unanimously reached the conclusion that stock prices can be predicted. The fundamental theory called the Random Walk Hypothesis claims that stock prices evolve around the random walk, and thus it is impossible to predict their future value. Thus, theory has roots in the influential Fama's (1997) work. In specific, stock prices are influenced by a multitude of factors, including economic indicators, company performance, geopolitical events, investor sentiment, news, and more. These factors interact in complex ways, leading to a high degree of randomness in stock price movements.

Even though this theory indicates that stock price movements cannot be accurately foreseeable, scholarly knowledge has been developing around the best-fit methods to explain the future. This particularly holds true for statistical, pattern recognition, machine learning, and sentiment analysis approaches, alongside some hybrid techniques. There is no unequivocal voice among scholars and practitioners about the best approach, since some authors advocate statistical (see Islam and Nguyen 2020) whereas other advocate for machine learning approaches (see Singh et al. 2017, Nõu et al. 2023).

The focal point of this paper is machine learning approaches. The systematic overview of the machine learning techniques for predicting stock prices is given in Figure 1.

Figure 1. *Systematic Overview of Machine Learning Techniques for Predicting Stock Price Movements*



Source: Bustos and Pomares-Quimbaya 2020.

The use of machine learning for economic prediction has first been recorded by White (1988). New publications and implementations continue to add to the finance and computational intelligence literature. In the last few years, deep learning has strongly emerged as the best performing class of machine learning predictors in various implementation areas. Time series forecasting is no exception as such, in recent years an increasing number of forecasts based on various deep learning techniques have been introduced at appropriate conferences and journals.

Deep Learning Methods for Stock Price Prediction

Deep learning architectures such as deep neural networks and RNNs are used in speech recognition, natural language processing and bioinformatics. However, the complex task of training a model can be described by a hierarchical structure, and when simple tasks are stacked on top of each other, they get a deep structure with many layers. For this reason, this approach is called deep learning. Recurrent Neural Networks (RNNs) and LSTMs are examples of deep learning models (see Bustos and Pomeras-Quimbaya 2020).

There are many reasons why deep learning is important to the field of finance. First, the availability of large data sets that are collected more quickly than in other fields. Second, certain financial applications depend on the speed and emergence of efficient machine learning hardware to achieve a level of responsiveness that is critical to the viability of a trading algorithm. Third, a large part of finance involves recognizing patterns of data usage, where different inputs are modeled to predict outputs. For example, stock market forecasting can be based on many variables (stock price data flow, interest rates, volatility, etc.). Another case is in consumer banking, where customers are characterized by a myriad of variables to determine which products to offer them or to calculate the likelihood of retention. It can be noted that pattern recognition in big data is analogous to the ImageNet problem. Thus, DL architectures that can learn to recognize an image can be used to learn to recognize stock market signatures that predict the direction of index movement. What DL discovers in the data, which cannot be discovered by standard economic methods, are "non-linearities" (see Culkin and Das 2017).

The main challenge for further research in this area is to simultaneously consider numerous factors in modeling financial data. In the search for factors that explain expected stock returns, a few potential candidates have been found using economic methods, such as accounting data, macroeconomic data, and news. Stock price forecasts that consider several predetermined factors can lead to inaccurate forecasting, because they maintain partial information or an ineffective combination of factors. Therefore, currently one of the most important tasks in finance is to develop a method that effectively integrates various factors into the forecasting process. Several recent studies have begun to use deep learning (see Lee and Yoo 2019).

Forecasting the stock market is significant in finance and is receiving more and more attention, since if the right market movement is successfully predicted, investors can be successfully guided. Researchers have proposed many models using different fundamentals, technical and time series forecasting techniques to make the forecasts competitive (see Abhyankar et al. 1997).

Event studies, introduced by Fama (1997), provide useful evidence of how stock prices react to information. Many studies focus on returns in a short period (a few days) around a clearly defined event date. The advantage of this approach is that as daily expected yields are close to zero, models for expected vegetable yields do not have a large impact on inferences about abnormal yields. The assumption of studies that focus on short return periods is that any lag in price response to an event is short-lived. Some authors challenge this assumption,

arguing instead that stock prices adjust slowly to information, so to examine market inefficiency one needs to examine returns over longer time periods.

Investors make decisions based on a variety of factors, including the consumer price index, the price-to-earnings ratio, and other news-reported events. To aid in their modern decisions, many automatic ways to automatically analyze that information have been proposed in the last decade (see Akita et al. 2016).

Statistical models such as autoregressive moving average models (ARIMA) and linear regression have been used to predict share prices. The best ARIMA model has done a satisfactory job in predicting the share price of Nokia and Zenit Bank. Also, the emergence of machine learning has led researchers to focus on various techniques such as artificial neural networks and genetic algorithms for time series forecasting (see Shah et al. 2018).

Long-Short Term Memory (LSTM) for Stock Price Movement Prediction

Neural networks with complex interconnections make up biological learning systems. As fundamental components, neurons receive real-valued input vectors and produce output values that correspond to those input values. In the typical neural network typology, the feedforward neural network is one of the most popular forms. These networks are organized into layers that include output, input, and—most importantly—one or more hidden layers. Because their primary purpose is statistical categorization, feedforward neural networks must work within the limitations of a consistent input-to-output mapping.

For modeling prediction tasks, a so-called dynamic classifier is required. We can extend feedforward neural networks for dynamic classification. To achieve this feature, it is necessary to feed signals from previous time steps back into the network. These networks with feedback loops are called Recurrent Neural Networks (RNNs). RNNs are limited to looking back approximately ten-time steps due to the recurrent signal, which can vanish or explode. This is resolved with Long Short-Term Memory (LSTM-RNN) recurrent neural networks. LSTM networks are to some extent biologically plausible and capable of learning over 1000-time steps, depending on the network (see Sangiorgio and Dercole 2020).

Unlike non-recurrent (non-reversible) neural networks, RNNs have recurrent connections between nodes and layers that can process input sequences of arbitrary lengths. However, training simplified RNNs can be a challenging task. Algorithms mostly manually update weights based on gradients, leading to the gradient vanishing or exploding problems. It has been proven that these issues are overcome by the development of 'Long Short-Term Memory' (LSTM).

LSTM is a special type of RNN that possesses internal memory and multiplicative gates. Different configurations of LSTM cells have been described since the introduction of LSTM in 1997 (see Hochreiter and Schmidhuber 1997).

LSTM networks overcome the gradient vanishing or exploding problem by intelligently forgetting past irrelevant information. Such networks have proven suitable for modeling sequential data, such as textual data or time series.

LSTM networks consist of memory cells that store information about the state over time using memory and output units that regulate and control the flow of

information through them. These networks use three types of gates - forget, input, and output gates. Forget gates serve as tools to discard irrelevant information from the past, retaining only relevant information for the current pass. Input gates control the information acting as input for the current network state. Old information from the forget gate and new information from the input gate are effectively aggregated into the cell state vector. The final output from the network at the current layer is produced by the output gate. This output can be seen as the predicted value that the model has calculated for the observed pass (see Mehtab et al. 2021).

Methods

In this section, we explain the rationale behind (1) the selection of LSTM for stock price movement predictions, (2) selection of five food-processing companies, and (3) selection of technical analysis related attributes used as inputs in the analysis.

Sample – Industry and Companies

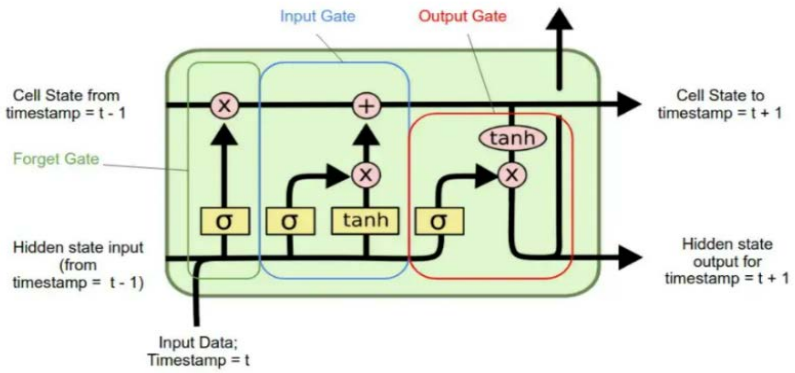
Industries that satisfy basic human needs, such as the food processing industry, are in high demand ever since the economic crisis induced by the pandemics of COVID-19 (see Clapp and Moseley 2020). Not only that the global food consumption grows at a staggering rate with a projection that the world will surpass 3000 kcal per capita per day (see Vasileska and Rechkoska 2012), but the consumer demands have been shifting toward the higher quality – health and wellness – products (see Nunes et al. 2020). Accordingly, the food-processing industry is expected to grow over the next decades, making this industry attractive for long-term investments.

The market power in the agrifood industry has been highly concentrated. Some authors even emphasize the negative effects of 'common ownership' – largest firms across a single sector sharing the same owners (see Clapp 2019). It should be mentioned that the 25 world's largest companies generated $1.5 trillion in revenue in 2022 (see Sorvino 2022). For this study, we selected five out of these 25 companies: PEP (PepsiCo), TSN (Tyson Foods), NSRGY (Nestle), JBSAY (JBS S.A.), and KHC (The Kraft Heinz Company) as a sample for our analysis.

Experimental Environment – Units of Observations and Attributes

Hidden state input from timestamp t-1: $h_{t-1} = [1, 2, 3]$, input data timestamp t: $x_t = [4, 5, 6]$. Assumption is that each LSTM layer contains three LSTM units. Each unit build identically is given in Figure 2, but each learn different thing.

Figure 2. *Internal Mechanisms of Each Layer*



Source: Colah 2015.

Which means that have three *Cell state,* and entry matrix of *Forget gate* have dimension 3x6.

$$W_f = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & -1 \\ 5 & 6 & 7 & 8 & 9 & 10 \\ 3 & 4 & 5 & 6 & 7 & 8 \end{bmatrix} \quad b_f = [1, 2, 3]$$

Forget gate targets are calculated per function (1), where b_t is the Bayes vector.

$$f_t = \sigma\left(W_t\left[h_{t-1}, x_t\right] + b_t\right) \tag{1}$$

After considering everything, multiplying the inputs to the Forget gate yields the matrix (2).

$$W_f\left[h_{t-1}, x_t\right] + b_f = \begin{bmatrix} -6 \\ 175 \\ 133 \end{bmatrix} + \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix} = \begin{bmatrix} -5 \\ 177 \\ 136 \end{bmatrix} \tag{2}$$

By inserting everything that was previously obtained into the equation (1), the output from the *Forget gate* given below (3) is obtained.

$$f_t = \sigma(W_f\left[h_{t-1}, x_t\right] + b_f) = \sigma \begin{bmatrix} -5 \\ 177 \\ 136 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} \tag{3}$$

The *Cell state* is calculated using the formula (4) provided below.

$$C_t = f_t \cdot C_{t-1} + i_t \cdot \tilde{C}_t \tag{4}$$

The first component of formula (4) is the result of *Forget gate* and *Cell state* at the previous moment. Taking into account the value obtained for the *Forget gate,* let C_{t-1} = [5,5,5]. The Cell state formula's value can be found below (5).

$$C_t = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} 5 & 5 & 5 \end{bmatrix} + i_t \cdot \tilde{C}_t = \begin{bmatrix} 0 & 5 & 5 \end{bmatrix} + i_t \cdot \tilde{C}_t \tag{5}$$

The next step is to decide which information to store in the *Cell state*. Value i_t indicates which state is being updated and its size. Assume that:

$$W_i = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ 3 & 3 & 3 & 3 & 3 & 3 \end{bmatrix} \qquad b_i = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$$

And put it in formula for i_t the value given below has been obtained:

$$i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i) = \sigma(\begin{bmatrix} 22 \\ 42 \\ 64 \end{bmatrix}) = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

In a similar manner, assume that:

$$W_c = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ -3 & -3 & -3 & -3 & -3 & -3 \end{bmatrix} \qquad b_C = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$$

Inputting everything into the formula for $\widetilde{C}_t$ result in:

$$\tilde{C}_t = tanh(W_C \cdot [h_{t-1}, x_t] + b_C) = tanh(\begin{bmatrix} 22 \\ 42 \\ -62 \end{bmatrix}) = \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}$$

When formula (5) is filled with everything that has previously been acquired:

$$C_t = f_t \cdot C_{t-1} + i_t \cdot \tilde{C}_t = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} 5 \\ 5 \\ 5 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix} = \begin{bmatrix} 1 \\ 6 \\ 4 \end{bmatrix}$$

The output decision will be based on a filtered *Cell state*. First, a sigmoid layer is run to determine which state to display. Then the state of the cell is passed through the tangent hyperbolic (so that the values are between -1 and 1), and

multiplied by the output of the Ssigmoind gate so that only the selected parts are printed.

$$tang(C_t) = tang(\begin{bmatrix}1 & 6 & 4\end{bmatrix}) = \begin{bmatrix}0.76 & 0.9999 & 0.9999\end{bmatrix}$$

Suppose that:

$$o_t = \begin{bmatrix}0 & 0.5 & 1\end{bmatrix}$$

When everything put into formula: $h_t = o_t * tang(C_t)$, we get:

$$h_t = \begin{bmatrix}0 & 0.495 & 0.99\end{bmatrix}$$

Empirical Model

LSTM was used to create a model for stock price prediction. Prior to creating an empirical model, the data was pre-processed. First, we conducted the normalization of data using min-max scaler (see Saboor et al. 2020) where the data took value from 0 to 1. Afterwards, the data was split into two parts: (1) train and (2) test. Since the neural network is expected to be 3-dimensional (output, time steps and features), the function reshape was used. Number of rows (units of observation) was 1.417.

The model was made using 'Tensorflow' in Python as one of the most popular libraries for deep learning (see Pang et al. 2020). The model was sequential with 50 neurons in the first, and the additional 50 neurons in the second layer. Also, we added two dense (output) layers, one with 10 and the other with a single neuron.

Model Compiling

For the compilation, the Adam optimizer was used (see Kingma and Ba 2014). This optimization algorithm is used instead of the procedure of the stochastic gradient descent as it can iteratively update the weight of parameters (see Dogo et al. 2018).

To check how well the model is trained, we used mean square error as a loss function. The use of mean square error has already been recorded in LSTM-based financial predictions (see Wu et al. 2018).

Model Training

Two parameters were important for the model training: (1) Batch size – explaining how many observations the model will take into account prior to updating the weights, and (2) Epochs – how many observations will the model take into account during the test phase prior to end the testing (Ranjan 2020). The values for the different parameters '*Batch_size*' are given in Table 1.

Table 1. *Batch Size and Predicted Value for the Sampled Companies*

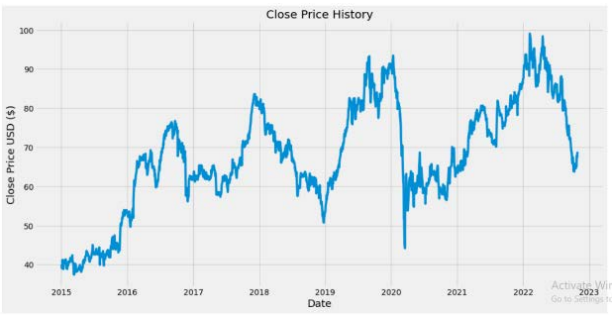
Company	Batch_size=32	Batch_size=64	Batch_size=128
PEP	180.1373	178.4878	173.6704
TSN	67.1967	66.5833	65.9999
NSRGY	107.3569	107.5837	106.9103
JBSAY	9.72186	9.5016	9.5032
KHC	36.7604	36.1036	36.1207

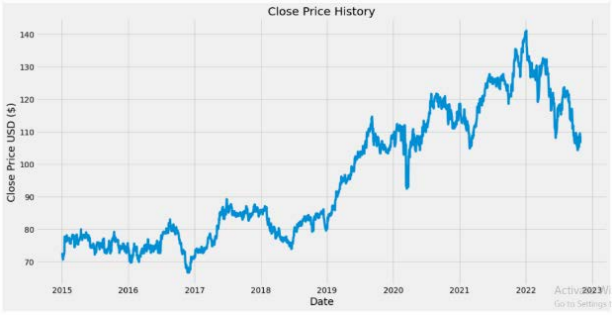
Results

Pre-Analysis

Prior to forecasting stock price of five selected companies, their time series were first decomposed. Actual price movements are given in Figure 3.

Figure 3. *Actual Price Movements*

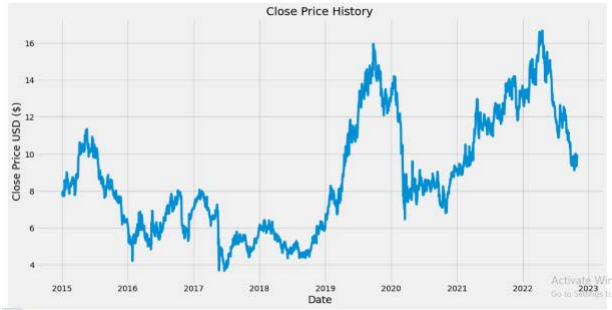




[PEP] Dickey-Fuler Test results
Test statistics: -0.495
p-value: 0.893
#Lags used: 9.000
Number of observations: 1,958
Critical Value (1%): -3.434
Critical Value (5%): -2.863
Critical Value (10%): -2.567

[TSN] Dickey-Fuler Test results
Test statistics: -1.223
p-value: 0.663
#Lags used: 8.000
Number of observations: 1,953
Critical Value (1%): -3.434
Critical Value (5%): -2.863
Critical Value (10%): -2.568

[NSRGY] Dickey-Fuler Test results
Test statistics: -0.495
p-value: 0.893
#Lags used: 8.000
Number of observations: 1,958
Critical Value (1%): -3.434
Critical Value (5%): -2.863
Critical Value (10%): -2.568



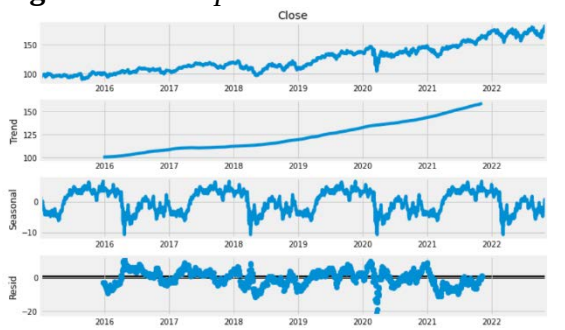
[JBSAY] Dickey-Fuler Test results
Test statistics: -1.713
p-value: 0.424
#Lags used: 1.000
Number of observations: 1,970
Critical Value (1%): -3.434
Critical Value (5%): -2.863
Critical Value (10%): -2.566

[KHC] Dickey-Fuler Test results
Test statistics: -0.906
p-value: 0.786
#Lags used: 1.000
Number of observations: 1,844
Critical Value (1%): -3.434
Critical Value (5%): -2.863
Critical Value (10%): -2.566

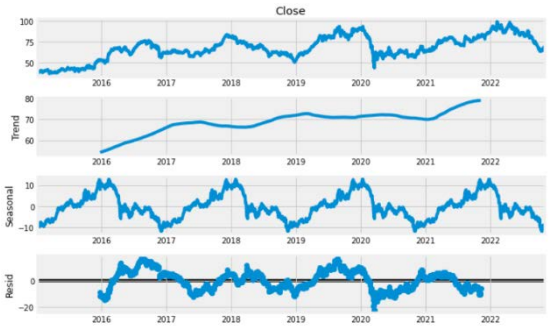
Source: authors' calculations.

Actual price movements were first decomposed. Decomposition of the time series was made with regards to the trend, cyclicity, and irregular movements (Qi and Zhang 2008), since these factors affect the stock price volatility (Castillo-Ponce et al. 2012). The results for all the observed companies are given in Figure 4.

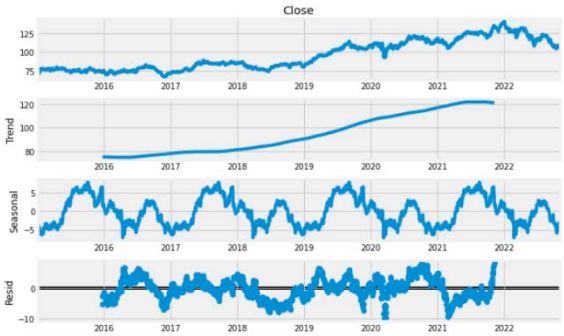
Figure 4. *Decomposed Values*



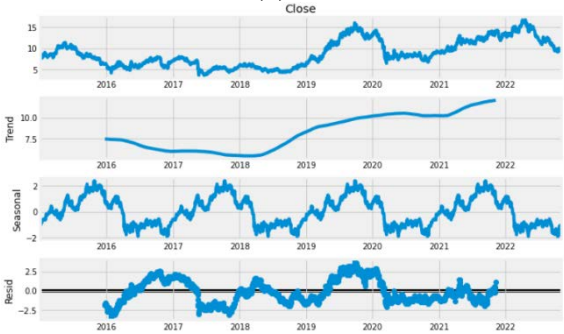
(1) PEP



(2) TSN



(3) NSRGY



(4) JBSAY

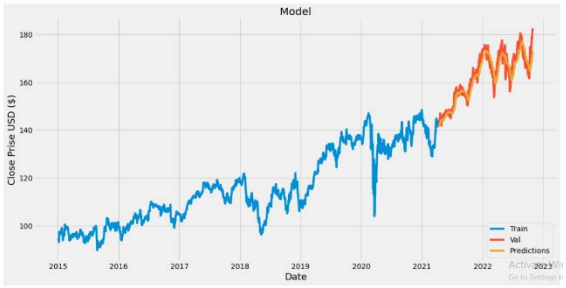
(5) KHC

Source: authors' calculations.

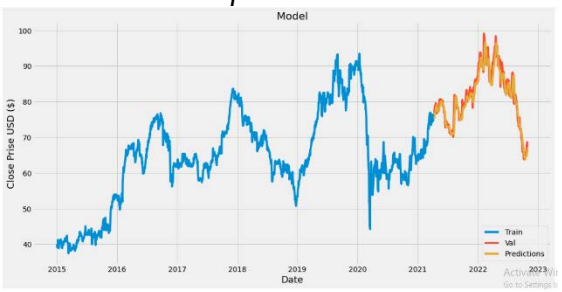
Main Analysis

After running the model on the observed set of companies, the predicted stock prices were close to the actual prices of stocks. For the given value of parameter batch_size=64 and epochs=10, the graphical display of movements in actual and predicted stock prices is given in Figure 5.

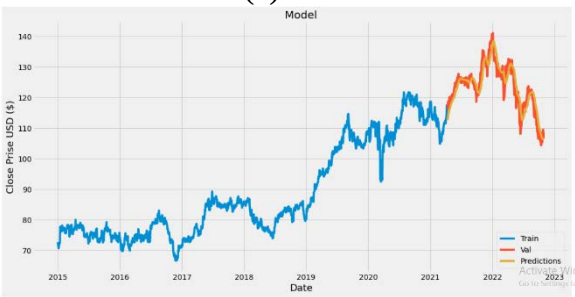
Figure 5. *Time Series – Predicted Versus Actual Price Movements of Stock*



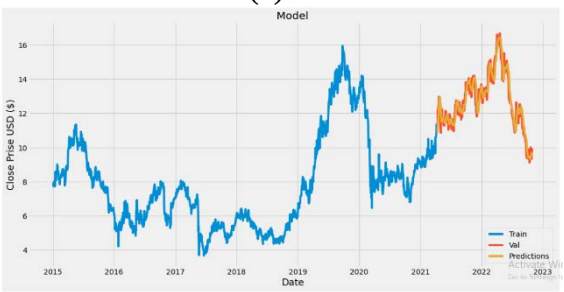
(1) PEP



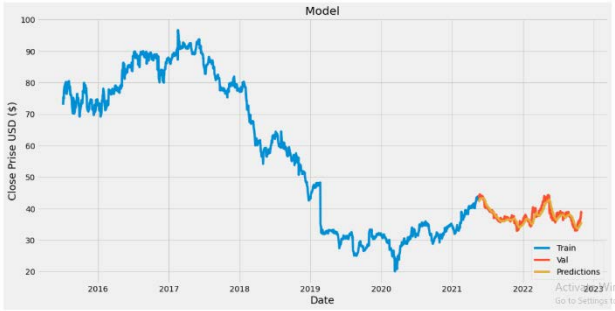
(2) TSN



(3) NSRGY



(4) JBSAY



Source: authors' calculations.

The model had a solid prediction result since the difference in average predicted and actual value is close (see Table 2).

Table 2. *Predicted Versus Actual Average Value of Stock Prices*

Company	Predicted value	Actual value
PEP	178.4878	178.2400
TSN	66.5833	67.4400
NSRGY	107.5837	108.07
JBSAY	9.5016	9.43
KHC	36.1036	38.1199

Discussion and Conclusions

Our study analyzed the predictability of stock prices of five global food-processing companies (PepsiCo, Tyson Foods, Nestle, JBS USA, The Kraft Heinz Company). For the prediction, we used the LSTM, a class of deep-learning models. The time series of five technical attributes were used in seven consecutive years to train the model. The LSTM algorithm showed very good results.

Because of its ability to assign different weights to input variables, the model automatically selects the most relevant variables. Hence, the ability of LSTM to capture the long-term dependence of time series and the ability to forecast financial time series (see Zou and Qu 2020). However, the disadvantage of the LSTM algorithm is that it takes a long time to train and requires a large sample of data (see Qian and Chen 2019).

Our findings can be valuable for investors, brokers and other stock market players. This approach is particularly important for investors who use algorithmic approaches to trading strategies.

Normally, predicting stock prices accurately is challenging due to the inherent volatility and randomness in financial markets. Machine learning models might not always provide precise predictions, and they should be used cautiously, considering various other factors that can influence stock prices. Accordingly, our study has a myriad of limitations. First, we observed only five global food-processing companies. This industry is well known for low-risk and low-returns (see Mukherjee et al. 2023). Hence, the predictability of stock prices is partially simplified.

Acknowledgments

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Design of an Efficient Turbofan Engine with Afterburners

By Justin Williams[*] & Yawo Ezunkpe[±]

In this paper we examine ways to potentially improve the overall efficiency of a turbofan engine with afterburners. A design similar to a turbofan engine used mostly in today's general commercial aviation aircraft was considered and a study was performed on its components individually using GasTurb and MATLAB software packages. The study revealed that the pressure and the temperature are the two main parameters which affect the overall efficiency of the turbofan engine with afterburners. In addition, the study showed the validation of the analytical results numerically using MATLAB and then visually using GasTurb. Finally, GasTurb was also used to perform the analysis of the 3-D plots that allowed for a complete understanding of how the efficiency of the turbofan engine was affected. As a result, different performance values were found, and showed that a turbofan engine with an afterburner can be made more efficient by increasing the pressure and the temperature in the combustion chambers.

Keywords: *efficiency, turbofan, afterburners, GasTurb, MATLAB*

Introduction

Many commercial aircraft are designed by gas turbine engines, which are either turbofan or turboprop. When it comes to the design of a turbofan engine, many engineers are trying to increase the efficiency of the turbofan engine without affecting the fuel consumption, performance, endurance, etc. Most modern-day commercial airplanes use a turbo fan engine because of the high thrust it produces and because of the good fuel efficiency that it has. Many turbofan engines consist of the air inlet/fan section, compressor section, combustion section, turbine section and the exhaust/nozzle section. Many modern-day designers are focusing more on the power generation of the engine. In turn, this brings to conversation on the efficiency and performance aspects of the turbofan engine while including an afterburner.

The development of the propulsion system for a turbofan engine has had a lot of complex challenges. Most of the challenges were because of its multidimensional systems. There are different propulsion systems with higher efficiency that would decrease the amount of fuel and hence the environmental impact, especially the release of CO_2 (Balli 2017). There are different theories that prove that the turbofan engine is one of the most fuel-efficient airplane engines that has been developed. With the state-of-art technology that we have there are different ways that the overall efficiency of the turbofan engine can be improved. One way is to use the

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Adaptive Cycle Engine (ACE) concept. The Adaptive Cycle Engine (ACE) concept is proven to meet the demands of the turbofan engine in terms of performance requirements. The ACE has low specific fuel consumption in subsonic flight. The ACE model involves two different thermodynamic cycles (turbojet and turbofan) on the same system, which makes the aircraft replies to multi-purpose missions both in supersonic and subsonic flight (Balli 2017). Furthermore, since the ACE model involves a changing bypass ratio, it would be considered to have more advantages in regard to the overall efficiency, flight range and specific fuel consumption.

With all this in consideration, the main purpose of the present study is to study and improve the overall efficiency of the turbofan engine while incorporating an afterburner(s) into its engine cycle for commercial airplanes. The approach and procedures will follow the different sources included in this report that were used to analyze and design turbofan engines. A realistic design approach for the inclusion of afterburner(s) to a turbofan engine will be discussed throughout this report to provide more insight into the possibilities of this design.

The objective of this report is to study and improve the overall efficiency of the turbofan engine while incorporating an afterburner(s) into its engine cycle for commercial airplanes. The main method of analysis would be done by using computer software called GasTurb. This software will be used to simulate different gas turbines' performance calculations and optimizations.

The approach that was taken was to use a gas turbine software that will analyze the performance of the turbofan engine and optimization the calculations used to design the turbofan engine. The gas turbine software named GasTurb will be used to perform the necessary analyses for this study. The first step of the analysis will be to review and develop a turbofan engine geometry while including an afterburner. This will be done by researching a turbofan engine and its overall engine specifications. The specifications will involve the engines geometry, engine dimensions, compressor, combustor, and turbine. The different properties that would be researched are the freestream conditions (Mach Number, Temperature, Pressure) and Burner (Temperature). Furthermore, this step will help with the overall turbofan engine specifications.

The second step of the analysis is to do a steady state parametric cycle analysis for a turbofan engine while including an afterburner. The step will include a component analysis of the compressor, combustor, and turbine. Therefore, this step will help with the component analysis of the turbofan engine and afterburner.

The third step of the analysis is to do a computation analysis of the turbofan engine while integrating an afterburner using the gas turbine software; GasTurb. This step would define the computational framework of the turbofan engine. In addition to that, different simulations of the turbofan engine and the afterburner would be simulated under different constraints. Furthermore, this step will help with the computation analysis of the turbofan engine and afterburner.

Literature Review

Before we dive into the analysis of the current work, a literature review was conducted on how to improve the overall efficiency of a turbofan engine. This was done to get a better understanding of the concept of the afterburner(s). This was also done to get a better understanding of the concept of an afterburner. Lastly, one final literature review was done. The energy and performance optimization of an Adaptive Cycle Engine for Next Generation Combat Aircraft was long considered and studied. This study looked at how the Adaptive Cycle Engine (ACE) was one of the top methods that would fulfill the many multi-mission requirements of aircraft flight. This concept dealt with the deficiencies of conventional low bypass mixed turbofan engines. This study explained how two different methods are used to optimize the overall efficiency of a turbofan engine. The first method looked at the performance and design results of the ACE model and compared it with those of fixed cycle low bypass turbofan engine by using specific fuel consumption, specific thrust, power and efficiency parameters (Balli 2017). The second method looked at the different ways the design parameters such as, the ST and SFC values of the ACE model are analyzed for double bypass mode and single by-pass mode (Balli 2017). Overall, this study provides a well-developed approach to how to optimize the overall efficiency of a turbofan engine which can be referenced for this project. Furthermore, Exergy modeling for evaluating sustainability level of a high bypass Turbofan engine was set to be used on commercial aircraft. This study presents an exergy modeling to evaluate the sustainability level of a high bypass turbofan engine used on commercial aircrafts (Aygun et al. 2020). The PW4056 model turbofan engine was used to examine its sustainability under different flight conditions. As a result, a sustainability analysis was done to improve the exergy efficiency of the engine. Furthermore, this study provides what is needed to know to optimize the overall efficiency of a turbofan engine for this report. Also, it is very important to point out that the parametric study on exergy and NOx Metrics of turbofan engine under different design variables because this study examined the different effects of design variables on performance parameters for turbofan engines. This study looked at the effects of the bypass ratio and turbine inlet temperatures for a turbofan engine. The parametric cycle equations regarding turbofan engines are encoded to compute performance metrics, while conducting energy analysis.

Overall, this study looked at ways to improve and to find out optimum design variables in terms of ecofriendly aircraft activities (Aygun et al. 2022). Nevertheless, Exergy and Thermoeconomic Analysis of a Turbofan Engine During a Typical Commercial Flight is one of the very important concepts of this analysis. This article examined the design and improvement of energy conversion systems for a turbofan engine. The article presented an exergy-based analysis which analyzed the performance of a typical turbofan engine and its components. The analysis was meant to simulate the exergy efficiency over the entire flight cycle for commercial flight. From that the data gathered was used to model aircraft for commercial flight. Overall, this article provides exergy and thermoeconomic approaches to improve the efficiency of a turbofan engine. Furthermore, An Exergy Way to

Quantify Sustainability Metrics for A High Bypass Turbofan Engine is needed. This study examined a new methodology to meet the need of the growing concern of fuel efficiency for the design and operation of the turbofan engine. The new methodology is being developed here that proposes the use of exegetic metrics for mapping the exergy flows throughout high bypass turbofan engine at maximum thrust level for its sustainability assessment (Turan 2015). The engine that was used for this study had a net thrust force of 206 kN and was used in the first wide body, dual-aisle, and the largest commercial aircraft (Turan 2015). The study found that the exegetic sustainability method was an effective way to assess the sustainability of aircraft and aero engines and provides a good tool for designers, users, decision makers and researchers in green air transportation (Balli and Caliskan 2021). As result, it was found that the method made turbofan engines more sustainable for flight. Furthermore, this article will serve as a good reference to help improve the overall efficiency of a turbofan engine. Before the analysis was done for the current project a literature review was done involving how to improve the overall efficiency of a turbofan engine. This was done in order to get a better understanding of the concept.

Another literature review was done involving afterburner(s). This was also done to get a better understanding of the concept of an afterburner. Lastly, one final literature review was done involving the overall efficiency of the turbofan engine while incorporating an afterburner(s) into its engine cycle. The following sections summarize each literature review finds and their contribution to the project. Below is a list of the different books and articles used for the literature review.

Overall Efficiency of a Turbofan Engine Studies

Turbofan Engine Performances from Aviation, Thermodynamic and Environmental Perspectives

This study examined how the JT15D turbofan engine and its main subcomponents were assessed with the aviation, energy, exergy, environmental, and sustainability analyses (Balli and Caliskan 2021). These different subcomponents were analyzed in order to make the turbofan engine more efficient. After the analysis it was found that the combustion chamber has minimum rates of sustainable efficiency factor, exegetic efficiency and sustainability index, while it has utmost rates of ecological and environmental effect factors, fuel exergy waste ratio, irreversibility and productivity lack ratios (Akdeniz and Balli 2022). Finally, it was found that the combustion chamber and the low-pressure compressor components should be optimized for better performance of the system. Overall, this study provides an approach to how to optimize the overall efficiency of a turbofan engine which can be referenced for this project.

Impact of Different Fuel Usages on Thermodynamic Performances of a High Bypass Turbofan Engine Used in Commercial Aircraft

The study examined the different impacts of fuel usages on thermodynamic performances of a high bypass turbofan engine used in commercial aircraft. The

study examined the PW4056 engine to observe the different fuel effects on the thermodynamic performance of a turbofan engine (Asmedigitalcollection.asme.org 2015). The energy, exergy, and sustainability analyses were performed on this engine. All analyses that were performed started at the same dead state conditions. In order to compare the different fuel performances for this engine, nineteen thermodynamic performance metrics were adapted for the purpose of this study. The overall study serves as a good reference to help improve the overall efficiency of a turbofan engine.

Turbofan Engine Health Assessment from Flight Data

This study examines the different approaches to engine health by using wing data from an engine of a commercial short-range aircraft obtained after a year of flight time. This was done by using an on-wing data measurements that analyzed three different approaches. In order to obtain good overall efficiency of a turbofan engine, a diagnostic process was used to track any engine deterioration. By taking this approach it helps reduce any issues to the engine or the engines health while in flight. Furthermore, this study provides good information that will serve as a good reference to help improve the overall efficiency of a turbofan engine.

Making Turbofan Engines More Energy Efficient

This study examined the different ways to making a turbofan engine more energy efficient. The study reviewed the different interaction and effects of cycle pressure ratio, firing temperature, bypass ratio, and component efficiencies on installed fuel consumption (Szczepankowski and Przysowa 2022). Also, the different possibilities for improvements in energy efficiency with operating economics and environmental characteristics are identified and reviewed. Parametric data was constructed which showed the trade-offs in the areas of efficiency and economics. Lastly, the balance of factors in cost effective advanced turbofans is discussed. This overall study serves as a good reference to help improve the overall efficiency of a turbofan engine.

Afterburner(s) Studies: Thermal Degradation of Turbine Components in a Military Turbofan

This study looked at the failure analysis of the turbine components of the RD-33 turbofan which is operated by the Polish Air Force. The thermal and dynamic stresses of the turbofan engine was analyzed. The study explained how the design of the afterburner activation system is a significant contributor to accelerated degradation of the turbine components and premature grounding of engines (Szczepankowski and Przysowa 2022). It was mentioned that when the afterburner is activated, during the ignition and propagation of the flame, local overheating of the turbine components occurs and initiates their damage (SKYbrary Aviation Safety n.d.). Furthermore, to combat this issue actions were proposed that would stop the negative impact of the afterburner. Overall, this study provides a well-developed approach to understanding how an afterburner work in regards to optimizing the overall efficiency of a turbofan engine.

Afterburner

This article gives an overview on how an afterburner works. The article examines how an afterburner is to provide a thrust increase. The article mentions that afterburning is normally achieved when the fuel is injected into a jet pipe downstream of the turbine. It was mentioned that; the advantage of afterburning is to significantly increased thrust; the disadvantage is its very high fuel consumption and inefficiencies (Farokhi 2021). Furthermore, this article gives a better understanding on how an afterburner works which will help optimize the overall efficiency of a turbofan engine for this report.

Afterburners. In: Aerothermodynamics of Aircraft Engine Components.

This book gives a general overview on how an afterburner works. This text went over the different characteristics of an afterburner. In addition to that, it explained the different flight conditions that an afterburner can be used under. The text explains the basic principles and concepts of propulsion combustion and goes over the different processes, limitations and analytical methods. Furthermore, this text book serves as a good reference for subject regarding afterburners.

Turbofan Engine while Incorporating an Afterburner(s) (Augmented Turbofan) into its Engine Cycle Studies

Propulsion and Power: An Exploration of Gas Turbine Performance Modeling

This text addresses the preliminary design of gas turbine engines, as well as the associated performance calculations. The text mentions how thermodynamics and turbomachinery is used throughout the design process for gas turbine engines. In addition to that, the text describes the background of augmented turbofan engines and their performances. Furthermore, this text is a good reference for the subject regarding augmented turbofan engines.

Developments in High-Speed Vehicle Propulsion Systems

This study explains the different technological achievements associated to the combined cycle engines such as the augmented turbofan engine. Some of the technologies that was described were the thermal management and how the afterburner was integrated with the turbofan engine. The study gave a better understanding on how the augmented turbofan propulsion systems are developed. Overall, this study would be good reference for understanding how augmented turbofan engine is developed.

Aircraft Propulsion: Cleaner, Leaner, and Greener

This text examines the new technologies for propulsion and power, like turbofan propulsion systems. The text gave a thorough intro into the different innovations in aircraft gas turbine engines. These innovations evolved new engine concepts, and new vehicles an exploration of compressible flow with friction and heat, including a brief review of thermodynamics, isentropic process and flow, and conservation principles (Elsevier Science 2014). In addition to that, a discussion on gas turbine engine cycle analysis was given. This would in turn help with the design of the gas turbine engine cycle. Furthermore, this text provides information

needed to get a better understanding on the different aircraft propulsion systems for this study.

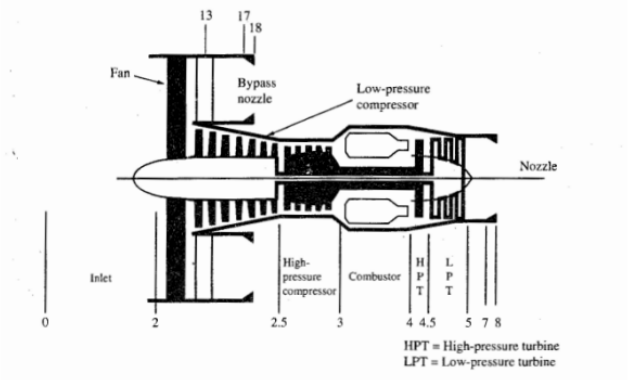
Combustion in Advanced Gas Turbine Systems

This text looks at different design considerations in advanced gas turbine combustion chambers, combustion in industrial gas turbines, and the overall combustion cycle. The type of engine that the study was based on was the Rolls-Royce Spey engine. Discussions focus on mechanical condition, carbon-formation and exhaust smoke, system requirements, fuel oil ash deposition and corrosion, combustion-system design, performance requirements, types of primary zone, fuel injection, and combustion chamber types (Mattingly and Ohain 2014). The text also explains subsonic flow flame holder studies using a low-pressure simulation technique and different augmentation systems for turbofan engines. Overall, this study provides a well-developed approach to understanding how a turbofan engine can incorporated an afterburner into its engine cycle.

Methodology/Materials and Methods

Turbofan engines have been used as a means of propulsion for airplanes for over 8 decades. In the early years of development, the turbofan engine was not as fuel-efficient as it could have been. The reason for this is because their overall pressure ratio and turbine inlet temperature were severely limited by the technology and materials available at that time. However, as technology advanced throughout the years the turbofan engine is now one of the most fuel-efficient engines ever made. The turbofan is a portion of the turbine work used to supply power to the fan. Generally, the turbofan engine is more economical and efficient than the turbojet engine. The thrust specific fuel consumption is lower for turbofans and indicates a more economical operation. The turbofan also accelerates a larger mass of air to a lower velocity than a turbojet for a higher propulsive efficiency (Academic Dictionaries and Encyclopedias n.d.). A schematic of a turbofan engine is shown in Figure 1.

Figure 1. *Schematic of a Turbofan Engine*



The turbofan engine that will be studied for this report is the General Electric GE90-115B shown in Figure 2. The GE90-115B was developed from a list of General Electric GE90 turbofan engines. The GE90 engines is a family of high-bypass turbofan engines built by GE-Aviation for the Boeing 777, with thrust ranging from 74,000 to 115,000 lbf (329 to 512 kN). It was first introduced in November 1995 on British Airways' 777s and is only available on the 777[1]. In 1995, the GE90 engine debuted aboard a British Airways 777 airplane. Early GE90 engine models boasted outputs between 74,000 and 94,000 lbs. of thrust, and today it remains the world's largest turbofan engine. GE has continued to improve upon the GE90 design with larger variants such as the GE90 – 11B turbofan engine. This engine was built for Boeing's largest 777 models 777-200LR and 777-300ER. In 2005 the GE90-115B engine was selected to power the Boeing 777-300ER (2004), the Boeing 777-200LR Worldliner (2006) and the Boeing 777 Freighter airplane. The GE90-115B 115,000-lb class engine was developed to meet the requirements of longer-range Boeing 777-200LR and Boeing 777-300ER aircraft. It is considered the world's most powerful jet engine and has set many aviation records. It was developed in April of 2004 powering Air France's Boeing 777-300ER (ScienceDirect Topics n.d.).

Figure 2. *GE90-115B Turbofan Engine*

Governing Equations

There are multiple equations that govern the field of propulsion. For this report the governing equations will be in the area of Thermodynamics, Parametric Cycle Analysis of Ideal Engines, Component Performance, Parametric Cycle Analysis of Real Engines, Engine Performance Analysis and Inlets, Nozzles, and Combustion Systems. These areas of interest were picked from the textbook Elements of Gas Turbine Propulsion by Jack D. Mattingly. The governing equations were used to design the properties for the compressor, combustor, and turbine for a turbofan engine with an afterburner. The formulas that were used for the thermodynamics of the turbofan engine design was:

[1]https://www.deagel.com/Propulsion%20Systems/GE90/a001376.

The Uninstalled Thrust F with a single inlet and single exhaust

$$F = \frac{(mdot_0 + mdot_f)V_e + mdot_0 V_o}{g_c} + (P_e + P_0)A_e$$

The Uninstalled Thrust Equation

$$F = \frac{(mdot_0 + mdot_f)V_e - mdot_0 V_o}{g_c} \quad \text{for } P_e = P_o$$

The second performance parameter is the thrust specific fuel consumption (S and TSFC). This is the rate of fuel use by the propulsion system per unit of thrust produced. The uninstalled fuel consumption S and installed fuel consumption TSFC is written in equation form as:

$$S = \frac{mdot_f}{F}$$

$$TSFC = \frac{mdot_f}{T}$$

The thermal efficiency of an engine is one useful engine performance parameter. Thermal efficiency is defined as the net rate of organized energy out of the engine which is then divided by the rate of thermal energy available from the fuel in the engine. The fuel's available thermal energy is equal to the mass flow rate of the fuel times the fuel heating value.

$$\eta_T = \frac{\dot{W}_{out}}{\dot{Q}_{in}}$$

Propulsive efficiency is the ratio of the aircraft power to the power out of the engine as shown in the equation below.

$$\eta_P = \frac{TV_0}{\dot{W}_{out}}$$

The thermal and propulsive efficiencies can be combined to give the overall efficiency. When multiplying the propulsive efficiency by the thermal efficiency the overall efficiency of the propulsion system is formed as shown in the equation below.

$$\eta_O = \eta_P \eta_T$$

$$\eta_O = \frac{TV_0}{\dot{Q}_{in}}$$

The next set of equations are used to solve the parametric cycle analysis for ideal engines. The cycle analysis studies the thermodynamic changes of the working fluid as it flows through the engine. The parametric cycle analysis determines the performance of engines at different flight conditions arid values of design choice and design limit parameters (Mattingly and Ohain 2014). In order to find the total/static temperature and pressure ratios of a free stream, the equations below are used.

$$\tau_r = \frac{T_{t0}}{T_0} = 1 + \frac{\gamma - 1}{2} M_0^2$$

$$\pi_r = \frac{P_{t0}}{P_0} = \left(1 + \frac{\gamma - 1}{2} M_0^2\right)^{\gamma/(\gamma-1)}$$

Following the equations mentioned above, the rest of the report uses equations and concepts from chapters Component Performance, Parametric Cycle Analysis of Real Engines, Engine Performance Analysis and Inlets, Nozzles, and Combustion Systems. These concepts will be used to design the properties for the compressor, combustor and turbine for a turbofan engine with an afterburner.

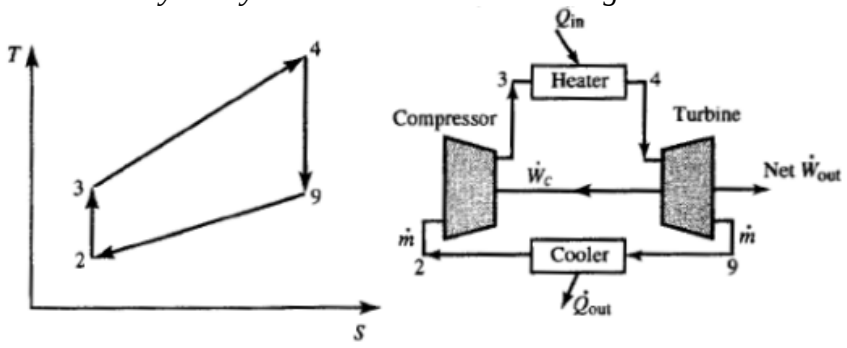
Theory

The Brayton power cycle is a model used in thermodynamics. This cycle can be used for an ideal gas turbofan engine. The Brayton cycle consists of four different thermodynamic processes.

1) *The Isentropic Compression Process (From 2 to 3)*
2) *The Constant-Pressure Head Addition Process (From 3 to 4)*
3) *The Isentropic Expansion Process (From 4 to 9)*
4) *The Constant-Pressure Head Rejection Process (From 9 to 2)*

Figure 3 shows a pictorial example of the Brayton cycle, which includes a TS-diagram and its four different thermodynamic processes:

Figure 3. *The Brayton Cycle which Includes a TS-Diagram*



For the Brayton cycle when the process starts and goes through the compressor and then the turbine it is considered to be reversible and adiabatic which is an isentropic process. In addition to that, when the process passes through the heater and cooler, it is considered to be the constant pressure process of the Brayton cycle. When the Brayton cycle passes through both the compressor and the turbine it is considered to be reversible and adiabatic (isentropic). For the process that goes through the heater and cooler is considered to be constant-pressure (Mattingly and Ohain 2014).

Since the engine that's going to be modeled for this report has an afterburner, Figure 4 shows a pictorial example of the Brayton cycle with an afterburner, which includes a TS-diagram and its different thermodynamic processes.

Figure 4. *The Brayton Cycle with an Afterburner which Includes a TS-Diagram*

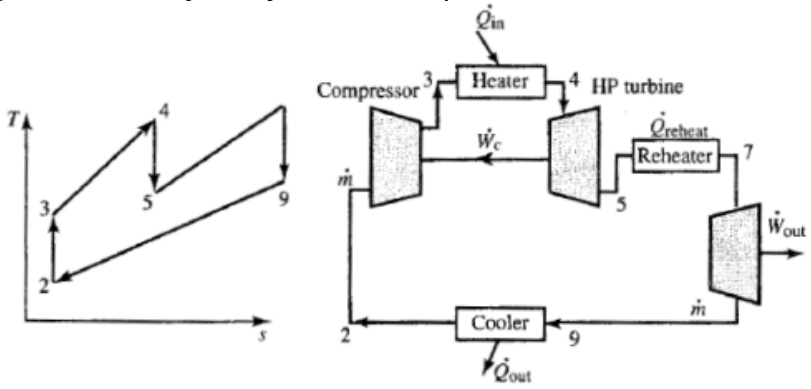


Figure 4 shows the Brayton cycle with reheat. The addition of reheat to the cycle increases the specific power of the free turbine and reduces the thermal efficiency (Mattingly and Ohain 2014). The cycle analysis studies the different thermodynamic changes of the working fluid as it flows through the engine. It is divided into two types of analysis: parametric cycle analysis and engine performance analysis. Parametric cycle analysis determines the performance of engines at different flight conditions arid values of design choice and design limit parameters. Engine performance analysis determines the performance of a specific engine at all flight conditions and throttle settings (Mattingly and Ohain 2014).

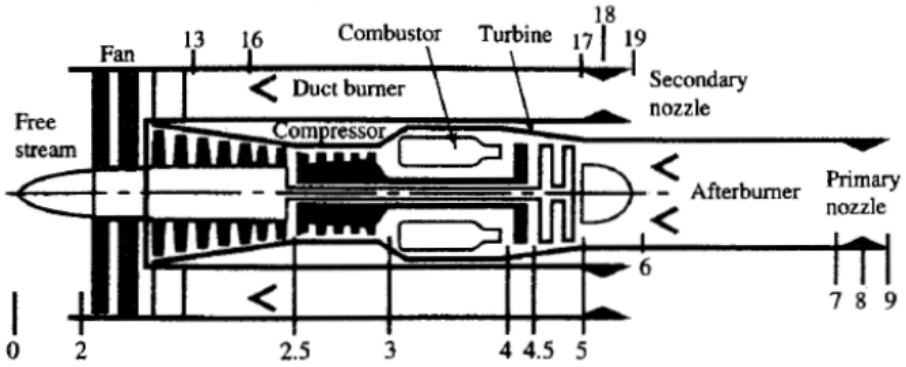
The main objective of the parametric cycle analysis is to relate the engine performance parameters to the design choices, the design limitations, and the flight environment. From the parametric cycle analysis, it can easily be determined which engine type and component design characteristics best satisfy a particular need. In other words, the parametric cycle analysis will relate the engine performance parameters such as the thrust and thrust specific fuel consumption, the design choices such as the compressor pressure ratio, bypass ratio, etc. the design limitations such as the burner exit temperature, compressor exit pressure, etc. and lastly the flight environment such as the Mach number, ambient temperature, etc. From these parameters the parametric cycle analysis can determine what the engine type would be such as a turbojet or turbofan engine and the component design characteristics such as the range of the aircraft flight. Therefore, the realistic values from this cycle analysis can help design a realistic turbofan engine.

The Steps of the Parametric Cycle Analysis Process

The general steps that would be used in order to perform a steady state parametric cycle analysis for a turbofan engine with an afterburner for mixed

exhaust streams would be the steps from the engine parametric cycle analysis for a jet engine with a single inlet and single exhaust.

Figure 5. *A Gas Turbine Engine with Station Numbering Used to Analysis the Turbofan Engine Flows*



Furthermore, Figure 5 will be used as a guide to analyze the parametric cycle analysis for real engines. The next chapter of this report will cover the analysis using the parametric cycle analysis for real engines. The equations and concepts will be used to design the properties for the compressor, combustor, and turbine for a turbofan engine with an afterburner.

Results and Discussion

A Parametric Cycle Analysis for a 2 Spool Mixed Turbofan Engine with an Afterburner Using GasTurb Software

This chapter of the report will go over the process used to obtain the values for a 2-spool mixed turbofan engine with an afterburner using GasTurb as the main software package. GasTurb is a gas turbine performance calculation and optimization program. It simulates most of the gas turbine configurations in use for propulsion or for power generation. Therefore, a basic understanding of turbofan engine performance calculations was used to make best use of this software. The software was used to conduct a design point calculation using a turbofan engine with an afterburner. Also, it was used to calculate basic thermodynamics properties for a turbofan engine. Next, the software was used to calculate a gas turbine cycle using the design point calculation, the enthalpy-entropy diagram (H-S diagram), the temperature-entropy (T-S diagram) and the pressure-volume (P-V diagram). The design parametric study such as the use of conducting parametric studies, contours and design Limits. Then the off-design simulations such as the use of off-design point calculation, usage of component maps, and the usage of operating lines to view different graphs. Lastly, the design of the engine geometry was determined.

A Parametric Cycle Analysis for a 2 Spool Mixed Turbofan Engine with an Afterburner

The 2-spool mixed turbofan engine with an afterburner design configuration will be used for this study. The input data for a 2-spool mixed turbofan engine with an afterburner were generated by the GasTurb software. The most important input design parameters are listed in Table 1 below. The parameters such as the Burner Exit Temperature and the Mixer Efficiency played an important role when it came to the overall efficiency of the turbofan engine.

Table 1. *Input Design Parameters*

Property	*Unit*	*Value*	*Comment*
Intake Pressure Ratio		-0.99	
No (0) or Average (1) Core dP/P		1	
Inner Fan Pressure Ratio		2.5	
Booster Map Type (0/1/2)		0	used for off design only
Outer Fan Pressure Ratio		3	
Compr. Interduct Press. Ratio		0.99	
HP Compressor Pressure Ratio		7	
Bypass Duct Pressure Ratio		0.97	
Turb. Interd. Ref. Press. Ratio		0.98	
Design Bypass Ratio		1	
Burner Exit Temperature	K	1600	
Burner Design Efficiency		0.9995	
Burner Partload Constant		1.6	used for off design only
Fuel Heating Value	MJ/kg	43.124	
Overboard Bleed	kg/s	0	
Power Offtake	kW	50	
HP Spool Mechanical Efficiency		1	
LP Spool Mechanical Efficiency		1	
Burner Pressure Ratio		0.97	
Turbine Exit Duct Press Ratio		0.98	
Hot Stream Mixer Press Ratio		0.99	
Cold Stream Mixer Press Ratio		0.99	
Mixed Stream Pressure Ratio		1	
Mixer Efficiency		0.5	
Design Mixer Mach Number		0.247	
Design Mixer Area	m^2	0	

The Burner Exit Temperature is 1,600K and the Mixer Efficiency is 0.5. The ambient conditions for the turbofan engine had a Mach number of 1.5 and had flight altitude of 11,000m. The Mach number and flight altitude came from the standard atmosphere, which was used to define the inlet conditions of the turbofan engine. Alternatively, the ambient pressure and the total pressure and temperature at the engine inlet was directly specified.

The stations of the 2-spool mixed turbofan engine with an afterburner will be examined next. The stations of the 2-spool mixed turbofan engine with an afterburner are labelled in accordance with SAE notation (Figures 6-7).

Figure 6. *A 2-Spool Mixed Turbofan Engine with an Afterburner Labelled with SAE Notation*

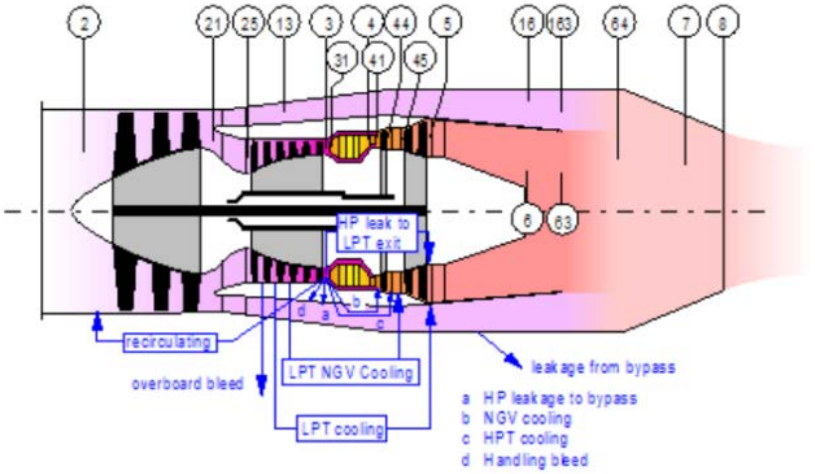
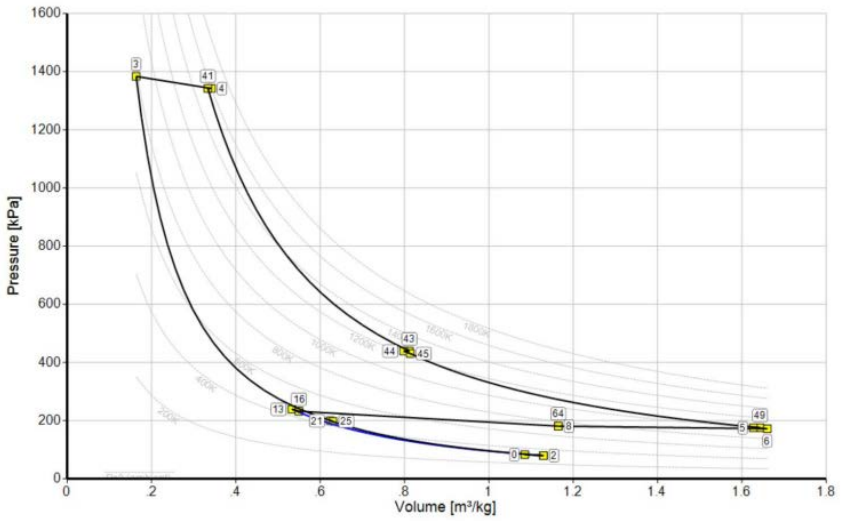


Figure 7. *The Pressure-Volume Diagram (P-V Diagram)*



In this section it was demonstrated how to calculate a turbofan engine cycle and also was able to use the GasTurb the iteration functions. The concepts from this section will be used to analyze the properties for the compressor, combustor and turbine for a turbofan engine with an afterburner.

The Off-Design Simulations for a 2 Spool mixed Turbofan Engine with an Afterburner

This final section of the chapter will go over how the off-design simulations will be performed. To start things off, calculating a single off-design point of a turbofan engine will be done first. The next step will be to examine how GasTurb uses component maps to calculate the off-design behavior. The last step will be to calculate the turbofan engine operating line. The study will continue to use the 2-spool mixed turbofan engine with an afterburner. First, we'll look at the low-pressure compressor map and the high-pressure compressor map of the turbofan engine that was generated. Figure 8 and Figure 9 show the low- and high-pressure compressor graphs, which show the compressors efficiency and relative spools speeds as a function of the mass flow and pressure ratio.

Figure 8. *The Low-Pressure Compressor Graph*

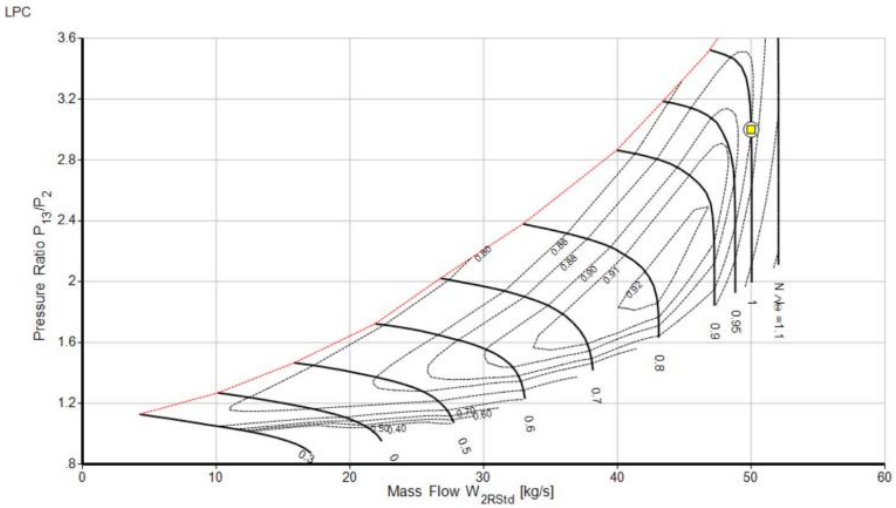
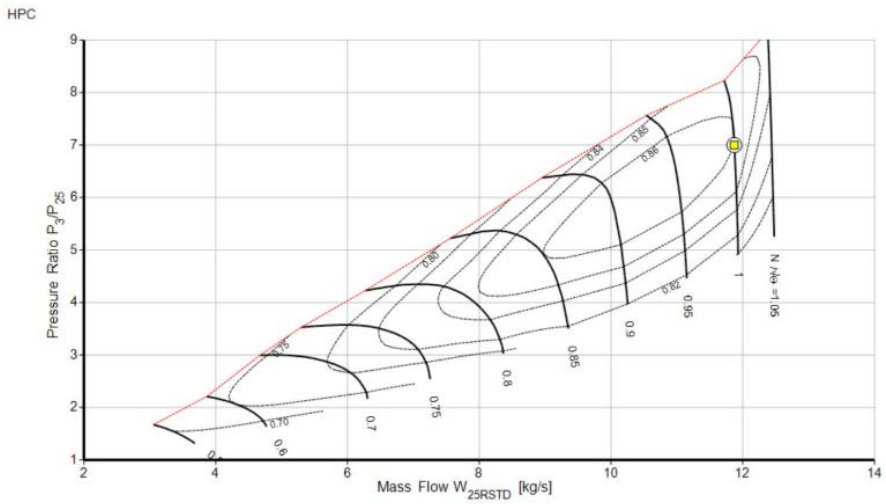


Figure 9. *The High-Pressure Compressor Graph*



In both figures the cycle design point is marked with a circle whilst the yellow square marks the calculated off-design operating point. As the two figures shows, the calculated design point of this off-design point are almost identical. This is due to the fact that, the GasTurb software has already calculated the off-design input for the cycle design point of the turbofan engine. In Figure 8 the low-pressure compressor ratio is 3, with a design compressor efficiency of 88% and a reduced mass flow of 50 kilogram per second. Also, in Figure 9 the high-pressure compressor ratio is 7, with a design compressor efficiency of 86% and a reduced mass flow of 12 kilogram per second. This shows that the low- and high-pressure compressor maps are close in value.

In this section it was demonstrated how the off-design simulations was done GasTurb software. In addition to that, this chapter demonstrated how to calculate a turbofan engine cycle and also was able to use the GasTurb the iteration functions. Also, how the GasTurb software uses parametric study to simplify the engine design process and to help us discover relationships between design variables and performance results. The next chapter of this report will cover the analysis done using the parametric cycle analysis for real engines. This analysis will be done using MATLAB software. The equations and concepts from this report will be used to design the properties for the compressor, combustor, and turbine for a turbofan engine with an afterburner.

Performance Analysis of a Turbofan Engine Using MATLAB

MATLAB was used to solve to model the velocity, temperature at the inlet, the pressure at the inlet, temperature of the fan, pressure of the fan, temperature of the compressor, pressure of the compressor, temperature of the high compressor and pressure of the high compressor. In addition to that, equations were set up using MATLAB for a performance analysis for a turbofan engine. Once these parameters were calculated, the results were then plotted against a range of Mach numbers. To find the results, code was used to calculate various parameters and then used to graph the results over a range of Mach numbers that ranged between Mach 0 to 5 for a ideal turbofan engine. The graphs were all created using MATLAB's built-in plotting functions. This allowed one to view the different graphs easily.

Figure 10 shows that when starting the velocity at Mach 0 and increasing to Mach 5, the results showed that the velocity reached 19.6 m/s in a linear fashion. Figure 11 shows that when starting the velocity at Mach 0 and increasing to Mach 5, the results showed that the pressure of the fan reached 2 x 107 Pa in an increasing fashion. Figure 12 shows that when starting the velocity at Mach 0 and increasing to Mach 5, the results showed that the pressure of the high compressor reached 2.25 x 108 Pa in an increasing fashion. Furthermore, one can note that for each graph as the Mach number increases so does the graphs.

Figure 10. *Velocity vs Mach number*

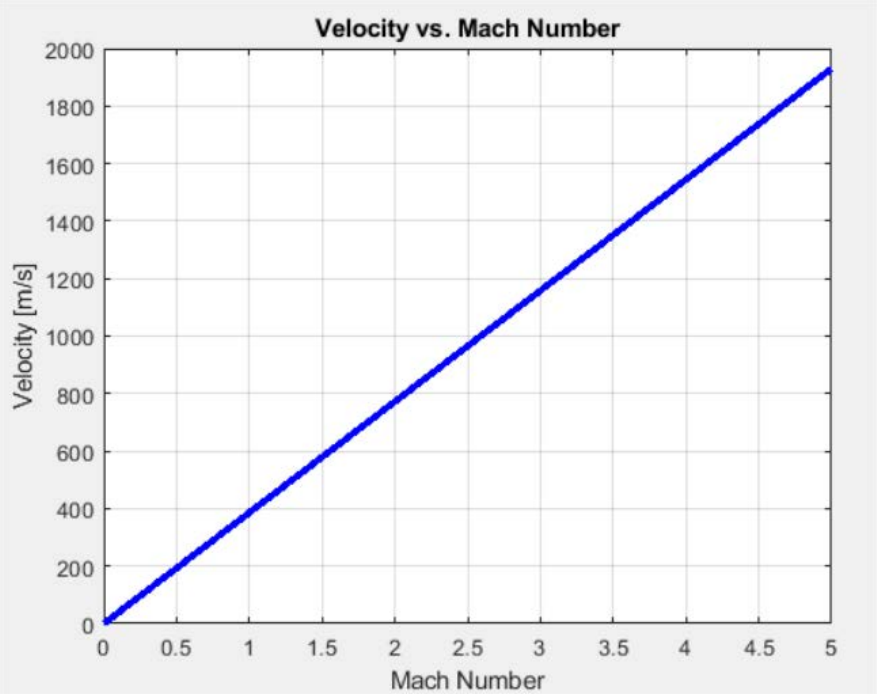


Figure 11. *Pressure of the Fan vs Mach number*

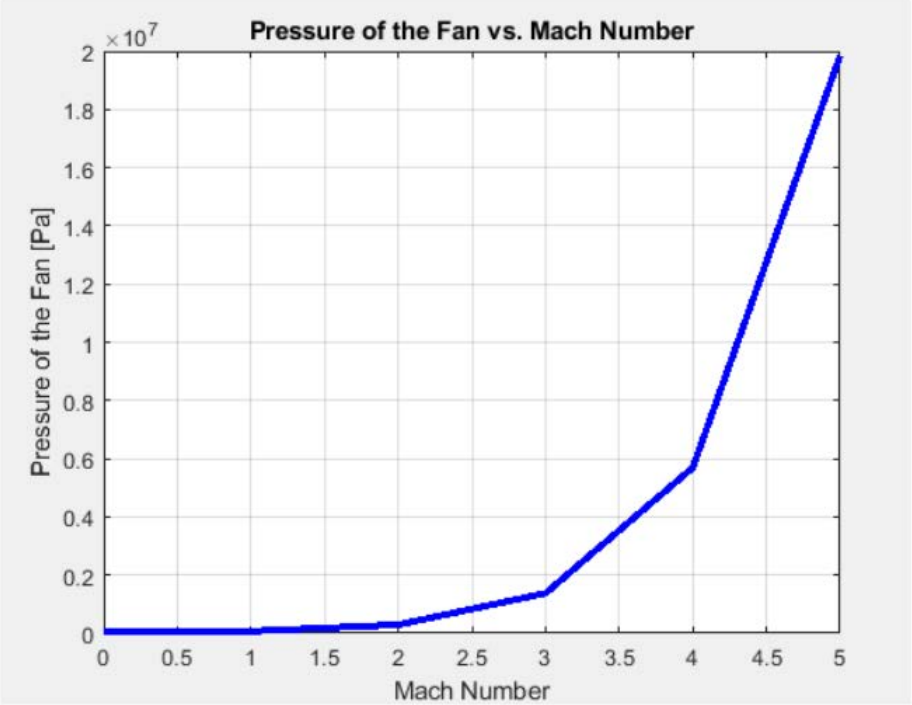
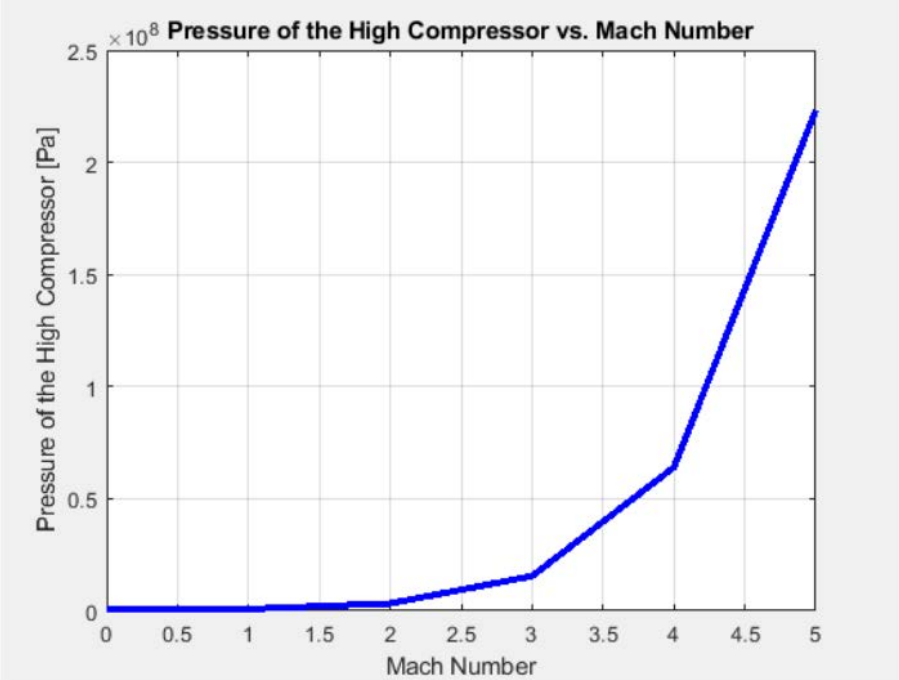


Figure 12. *Pressure of the High Compressor vs Mach number*



In this section the performance analysis of a turbofan engine was demonstrated using MATLAB. In addition to that, MATLAB was successfully able to calculate various parameters and then used to graph the results over a range of Mach numbers that ranged between 0 to 5.

Conclusions

The primary purpose of this study was to design an efficient turbofan engine that included afterburners. The modelling and simulation of the turbofan engine that included afterburners was done using GasTurb and MATLAB software packages. Since this turbofan engine was to include afterburners, it was greatly needed for the engine to be efficient. This meant that the design of the engine from its inlet to the afterburners should be designed efficiently to compress the high-speed air that would be flowing through it. Therefore, there were different simulations that were done at different Mach numbers. The Mach numbers were 0 through 5. The trends from the graphs were observed to have contour plots.

Theory states that if the pressure in the combustion chamber is high then there will be a chance for an efficient combustion process. At times there were slight discrepancies in the values calculated however, these discrepancies are possibly a result of an error in the MATLAB code. Nevertheless, this study was just a small step in designing an efficient turbofan engine with an afterburner. Building on this study, future studies can look at the numerous other combinations of mass flow rates of oxygen and other fuels. After the validation of the modelling and simulation

of the turbofan engine with an afterburner, different scenarios of the turbofan engine were studied as shown in the graphs.

In the future, new turbofan engine designs will possibly require new propulsion systems. Propulsion capabilities are essential when it comes to increasing the efficiency of the turbofan engine, the durability, mission proficiency, etc. Furthermore, this project has explored a possible future propulsion system design that included an afterburner. For this to be possible, new and improved additive materials could be explored as well as the manufacturing processes and technological advances which would provide solutions to issues. A system like this could be used to replace the traditional turbofan engine propulsion systems.

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The Making of the Liveable City: The Overlooked Aspects of Smart Cities Design

By Faten Mostafa Hatem[*]

This article examines the real potential of smart cities to offer a better experience to residents as people with more than just basic needs. This is done through a lens of design, urban encounters and on-site sensations. The topic is presented and discussed in four main themes; Facilitating the Making of Liveable City and Quality Experience, Mental Associations of the City, The Unique Intimacy of the Night Experience, Emotional Responses: Safety, Stress and Discomfort, and the Taste of the City: Character, Wayfinding and Monotony. This is done to facilitate analysis and communication. Nevertheless, the topics presented here should not be separated from one another. Various qualitative methods were used in the analysis of the Milton Keynes case study; this includes interviews, field observations and visual comparisons with other cases, allowing for a deeper understanding of the different capabilities of the different approaches. The results help to further fill the knowledge gap in the literature on the overlooked aspects of smart cities and provide better information for smart city design.

Keywords: *smart cities making, sustainability, city brain and smart cities metrics, smart cities standards, smart cities applications, governance, planning and policy*

Introduction

The research explores how different design aspects of the lived experience and sensations in smart city-making are being comprised for a dominant focus on the efficiency of infrastructure, basic function, and services. The interviews analysed as part of this paper engages parties involved in policymaking, technology, and smart city design to think, apply and produce them concerning the living experience in the city. The chosen case study Milton Keynes is recognized for being a living lab and has a strong vision and agenda supporting its development as a smart city, it also has a strong reputation for being one of the UK's fastest-growing and economically successful cities. The paper starts by exploring the attention given to the night experience in the case study's design, then it moves to explaining the sensations that the way its elements put together, and produce, and finally, it ends by describing the effect of neglecting certain characteristics of the built environment on placeness of the city. This helps to understand how important designing the human experience and providing good quality experiences and sensations is to making smart cities which render themselves better than other cities. The data collected and analyzed qualitatively revealed findings that are

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presented under themes strongly related to spatial aspects found to be compensated for the mere focus on technology. These include Facilitating the Making of Liveable City and Quality Experience, Mental Associations of the City, The Unique Intimacy of the Night Experience, Emotional Responses: Safety, Stress and Discomfort, and the Taste of the City: Character, Wayfinding and Monotony. Nevertheless, the thematic presentation is used to offer the argument in a way that makes it easier to grasp. This is not to suggest that these areas are to be understood or appreciated separately from each other or in silos. The findings reveal that Smart is focused on using and installing technology in the city as a market, assuming that basic services are what people need, using computer rationalities that are systematic and abstract dealing with the resident as a mere user to function at something. This overlooks the lived experience, feeling, and atmosphere of the city detaching the people from their habitat. On the other hand, art is highly focused on feeling the tools as a method of knowing them as well as the making of the perception, communicating with the people using a language that is powerful enough on the primitive level –the international human level to make them feel something, live something, or engage them to achieve something. This evokes a sense of belonging, ownership, and participation. Integrating art to develop smart cities in various ways; conducting research, making the city, and enhancing the level of engagement with people are recommended to generate more valid outcomes and a deeper understanding than old-fashioned ways of collecting and interpreting abstract data that sometimes reveal mixed outcomes.

Methods

To highlight the difference in the approach used in the case study through fieldwork and other recognized approaches, visual comparisons are presented in different forms throughout the paper, while explaining the difference in logic and associated failure or success. Seeking an in-depth understanding of the making process. The paper illustrates results from the case study approach that combines direct field observations and semi-structured interviews conducted with experts who experienced, lived, worked, and participated in the development of Milton Keynes. The notes taken on the field were interpreted with reflections on the difference recognized through a comparative approach that depends on visuals. This is to efficiently examine and feel the nuances that cannot be communicated fully merely by using words, especially given the context of atmosphere, emotions or affections, encounters .. etc. This resonates with the principle that even though a case study is a unit of analysis, it may include more than one case in which is called then a multiple-case design. Multiple or comparative case designs generate results that are found to be more convincing as it is derived from a set of cases, causing the whole design to be perceived as stronger or more robust than single-case designs (Wikfeldt 2016). In rare, unique or extreme cases the direction of the research design will be plausible by definition (Yin 2009, Karvonen 2020). Milton Keynes which is known for its prestige as being a Smart City is discovered to be an extreme case of using design/urban elements in a way that is merely focused on

the pleasure of the eye, detaching those elements of the city that could be of greatest power to enhance people`s lives, explore, deliver and evoke an engaging atmosphere. The case study is discussed through comparisons with other cities and approaches in terms of their spatial design and relation to shaping the experience in the city. The focus was practically to use noticed practices, products or ways of thinking noticed during field trips to other cities that were found beneficial to show the difference in how they reflect their atmosphere, identity and care for the resident's needs in the city. This appreciation and consideration of the lived experience, atmosphere and placemaking needed to be analysed and communicated using visual comparisons, reflections and highlights from the actual first-hand experience as well. Karvonen (2020) agrees that the search for smart cities is still in its infancy and that more critical understanding of the concepts, implications, and possibilities associated with the vision of smart cities is needed (Amin and Thrift 2002, Karvonen 2020). Fulfilling these needs will enable researchers to be more engaged with the debate instead of adding to the dominant critics on the "banality" of contemporary urban designs which are often exposed by "the rush to theoretical order" that is proven to be unproductive and incompliant with the complexities of urban visualities (Amin and Thrift 2002, Degen et al. 2008). Hence, producing knowledge on the process of making and developing smart cities can be severely impacted by factors in the process of conducting the study itself. Some of these include using traditional ways of conducting research on atmospheres as well as recycling the same views on previous data collected without further explorative questions or analysis with a new emphasis on certain areas. This issue in academia as a practice not only produces inefficient recycled views of previous literature, delaying any progression in the research because of the absence of higher efficiency and productivity found in more innovative ways of working. Working in silos produced unhelpful and rather contradictory outcomes. Whelan (2020) asserted visuals work better because they are quicker and more reliable than words when it comes to expressing meanings around the daily experience, providing important "complex, non-linear and dynamic entities" (Whelan 2020). Hence, using visuals in this study helped to provide rich pictures and engaging debates.

Supportive data included interviews from different resources such as the Living Archive, the BSC Gem of all Mechanisms podcast, a published interview with Prof. Michael Keith coordinator of Urban Transformation network (UT), one of the ESRC networks with over 80 research projects presenting urban challenges and development opportunities, as well as 22 multi-disciplinary interviews with various experts in Milton Keynes making and development, as they were conducted as part of the Smart Cities in the Making: Learning from Milton Keynes project funded by the Economic and Social Research Council (ESRC) (see more in Rose (2018).

Results

Facilitating the Making of Liveable City and Quality Experience

Bearing in mind the current views on what smart is and what it could be, the results argue that there could be a deeper understanding of the meaning of the label Smart City and the image of the authentic smart city. The basis of the view this research work offers relied on principles that stem from the process of conducting the research as well as the literature. The need for a more comprehensive and facilitating vocabulary has been expressed by many scholars reflecting on challenges that communication raises in the design process, research, and development projects of smart cities. Facilitating better communication is not only important to achieving predefined goals of the visionary smart city or project; it is rather essential to get a profound understanding of the actual experience and visuality of the city or urban spaces as the inhibitor perceives or interacts with it. However, studies on the city require not only critical tools and more accurate critical vocabulary, but also multiple theoreticsand methodologies and different approaches to discussing urban aesthetics (see also Ellard 2015, Foss 2018, Julier 2006, McLean 2019). The lack of proper vocabulary in addition to inheriting a fixed position that merely criticises design through a lens that focuses on the way urban design is used as a tool of the system, capitalism, or consumerism, hypnotising, and depoliticizing the public (Degen et al. 2008). Criticizing the inefficiency of the notion of "Smart" is a shared view among those involved in making smart cities. The inconvenience seems to be brought by the difficulty to define and measure what is meant by the term. Using the correct labels or phrases is helpful because it raises the efficiency of teamwork, as the long experience of an interviewed academic, a research director and a retired strategic consultant revealed. The same understanding and appreciation for the role labels can play in teamwork occurs in discussions on software development, in the BSC Gem of all Mechanisms podcast, Runciman (2020) explained that labels are fundamentally helpful to reduce ambiguity and increase the certainty that "we are not misled into thinking we are doing something as opposed to something else" (Runciman 2020).

Another point is the association with high tech which leads to rationalities that are focused on efficient services and devices in the city such as robots and autonomous vehicles, even though in terms of affects as an element contributing to the atmosphere of the city, they are not proven to have the same impact as other aspects and goals in terms of the socio-spatial, lived experience and wellbeing are either disconnected or undefined. These elements that are often perceived as what smart is, as shown in Figure 1 are essential to functional services but they are only a small part of what a smart city means or rather a better experience in the city could be like, as they become the old new after some time.

Figure 1. *Delivery Robots in Milton Keynes*

Interviews and discussions around the notion of Smart show a general dissatisfaction with the ambiguity of a term that is often used to express a sense of a futuristic, progressive, somewhat better style of cities. The impact of this uncertainty about what exactly smart is supposed to be or how to measure its delivery became more apparent when professionals who have experience working in smart cities governance and development projects were asked to filter and reflect on images representing relations between surroundings environments and human interactions, wellbeing, and needs. The direct quick answers revealed that these were not considered relevant not only to the notion and how smart cities are constructed but also to the visionary smart city. The same pattern was noticed after analysis of the interviews collected from supportive data provided by various resources stated previously. However, holding the position of an observer as the approach is engaging in an open debate, instead of recycling previous insights or data collected to criticise them, helped to reveal that human nature as well as a reflective and reflexive practice already exists in some level, however not deliberate, or consciously used in practices concerning Milton Keynes development as a smart city. Examples include projects to develop phone applications, clean mobility and an age-friendly app called Age UK Milton Keynes. The shared pattern of thinking is of focuses on how the managers namely notice, recall or imagine they would have liked or disliked using the service provided to make the question more about how to make it more enjoyable and attractive. Practical cases on this were clearly given by academics and a strategic consultant on energy and transport explaining what appeals to people as an essential asset to boost numbers of bus users instead of using the car. Also, statements a manager of a content marketing agency commented on the making process of a phone application that listed all of the different landmarks, celebrating the 50th anniversary of Milton Keynes saying: “There wasn’t anything around it, and the idea of it being called 50 Golden Icons was not exactly too encouraging to people to go and download. We wanted to create something a bit more inviting. We wanted to create something that had more of a challenging aspect to it. We wanted something a bit more

interesting". This way of thinking within marketing and IT companies which are engaged in constructing and developing smart cities is promising as it emphasises delivering the right thing instead of selling something as another expert and academic stated. Moreover, delivering a product not only on time but also by making it competitive by adding the user reaction to be the main focus while it is under development, in turn, makes the team add thoughtful elements to make it more engaging.

Also, making senior citizens able to use and interact with technology in the smart city as it develops a priority in addition to other statements revealing that making this category of resident more confident and comfortable about living with changes the future or the agenda of their city to progress as smart show a consideration of the human nature and the natural responses to change. However, other statements reveal the absence of proper understanding of the role that architecture of surroundings play especially concerning affecting human nature and needs, with some experts stating that the services that central areas of Milton Keynes offer such as catering, entertainment and shopping make the area surrounded by H5 (Portway) north going road, West Coast railway line to the west and towards the east through the Grand Union canal- the "heart" of the city. Other experts, academic and historic professionals stated the opposite; referring to the grid system, the split between historic and modern areas, and the land's lack of character in the architecture and typology of the city as reasons behind not having engaging collective places for people to offer as a real heart of the city while forcing a name of the centre to a line that is connecting the train station with the shopping mall shown in Figure 2.

Figure 2. *Central Milton Keynes (CMK) [35]*

A leading officer at services and support charity to age-friendly development in Milton Keynes added "you can have been living in Milton Keynes for 30, 40 years, but you're not using all parts of Milton Keynes. Like, Central Milton Keynes is very commerce-driven, the shopping centre, the marketplace, although there's lots going on we don't necessarily feel that people engage all the time." Direct observations and the researcher's first-hand experience of living a long time in different areas of Milton Keynes support the observations and reflections made on the case study, including that shopping is namely the dominating activity.

These features were emphasized by the way the city was originally planned using a grid system and abstract modern designs to imitate American cities. This also resulted in a lack of a "heart" or a clear centre of the city making the daily experience of the city more seamless, plain and unvaried. Related observations to this are discussed in more detail in the following themes, confirming the need to allow people to explore and experience how is it like to be in this particular city in an appealing way that exposes and observes how the different city elements affect their impression of the city.

Mental Impressions of the City

The Significance of a Good Quality Human Experience in the City

Human perception of architectural space involves intention as the generative force behind the experience of engaged sensations and impressions. The outer perception is engaged with physical phenomena such as the structural spatial entity and the inner perception is engaged by mental phenomena which is the motivation behind it. To upgrade the phenomenal experience architecture must stimulate both phenomena while expressing meaning taking into consideration the particularities of the site and circumstances. To develop a clear understanding of this integration between subjective and objective architects have to demonstrate the whole and analyse the partial perceptions. As architecture is not understood as a totality rather it is understood as a series of partial views or specific experiences. Architecture is powerfully inspirational when it is more stimulating as a whole than its individual parts. Thus, the building program needs to be balanced with the phenomena of material, space, detail, etc. (Pallasmaa 2012).

By stimulating certain neural activities of the brain through the integration between steadiness and ambiguity artists are empowering imagination such as the artworks that are represented in “incomplete” forms or in a mysterious story. According to Paul Sartre imagining is to be differentiated from realizing by intention and the orientation of the awareness towards the objects not by the objects themselves. The importance of imagination comes from the fact that images and visual perceptions are in the same zones of the brain which makes them equally real and sometimes it is more important as Anatole France once stated: “To know is nothing at all, to imagine is everything” (Pallasmaa 2011, Shelton et al. 2015, Tenner 2018, Webb 2006, Whelan 2020, Wikfeldt 2016, Wilding 2018, Yin 2009)[2].

[2]https://www.milton-keynes.gov.uk/your-council-and-elections/councillors-and-committees/map-parish-and-town-councils; https://www.bbc.com/news/uk-england-beds-bucks-herts-22038868; https://twitter.com/KensingtonRoyal/status/912626651057487873?ref_src=twsrc%5Etfw.

Figure 3. *A Sample of Road Signs and Logos of Milton Keynes*

Sources from left to right: (a): https://www.bbc.com/news/uk-england-beds-bucks-herts-22038868, (b): https://twitter.com/KensingtonRoyal/status/912626651057487873?ref_src=twsrc%5Etfw, (c): https://heritagemk.co.uk/.

The lack of a clear mental image of the city seems to be noticed clearly in the official logos, events and organisations where it is needed the most to communicate a symbol or a sense of the city (see Figure 3). On the contrary, the main characters used are overly simple and abstract using the abbreviation of the city name MK. On the other hand, other cities with a stronger mental image evoked by the means of their placeness, interesting skyline and architecture as well as the village area of Milton Keynes as shown in Figures 4-5, seem to be celebrating their identity while stimulating curiosity to know about the history of the place as a newcomer or the imagination to recall certain experiences or scenery of the city. This makes places memorable to people, which in turn boosts the sense of attachment.

Figure 4. (Left) *Symbols and logos in Milton Keynes Village and Broughton*
Figure 5. (Right) *Landmarks in Broughton Recognisable from a Distance*

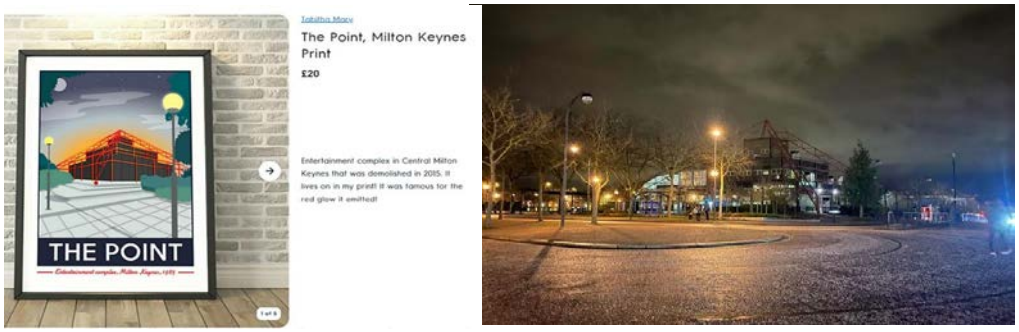
Visualisation as an effective method of communication has been around for at least 35000 (Whelan 2020). Exploring early maps and Portolan charts as shown in Figures 6-7 revealed that imagery and metal images of regions were communicated with a sense of their unique elements, identity, culture and atmosphere.

Figure 6. (Left) *Portolan Chart Showing Western Europe and North Africa, Messina, Italy-Around 1550; it was taken by the Author in the British Library, London*
Figure 7. (Right) *Chart of the Mediterranean, Black Sea, and the Coasts of Western Europe and Northwest Africa*[3]

The place which can be remembered is not only the unique but also the place which affected the body and generated enough engagement to hold in the personal experience of the world, thus the centre of this continuous interaction is the human body. Hence, the importance of having a strong mental image stems from the need to engage the body emotionally, as it is necessary to play with conscious and unconscious intentions creating a deeper dimension for the experience through integrating body and imagination with the surrounding environment rather than the shallow rationalism. The concepts of the "narcissistic and nihilistic eye" discussed by Pallasmaa (2011) trace the dominance of the eye in the modern age. The narcissistic eyes focus on artistic self-expression while approaching architecture apart from cultural, and mental connections and the nihilistic eye detaches and alienates the senses which is weakening the integration of the body when experiencing the world and contradict the construction guided by consideration of perception of surroundings through peripheral and haptic senses of the body for example found in traditional culture (Pallasmaa 2012). Similarly, focusing on what people miss about older times in Milton Keynes, historic roads being largely lost by modern developments of the new city were expressed in the higher emotional and atmospheric sensation of journeys he used to enjoy on both personal and professional levels as a historian who used to work and live in Milton Keynes. In addition, The Point (Figures 9-10), one of the historical landmarks has also been affected by the impact of time, the meaning of progress and the focus on certain aspects of development. The observations and visuals present the lost effects of the landmark which in turn impacted the overall atmosphere, wayfinding and experience. An artist expressed her affectionate memories of the times in an atmospheric painting showing the distinguishable lighting of the entertainment complex at night as shown in Figure 8.

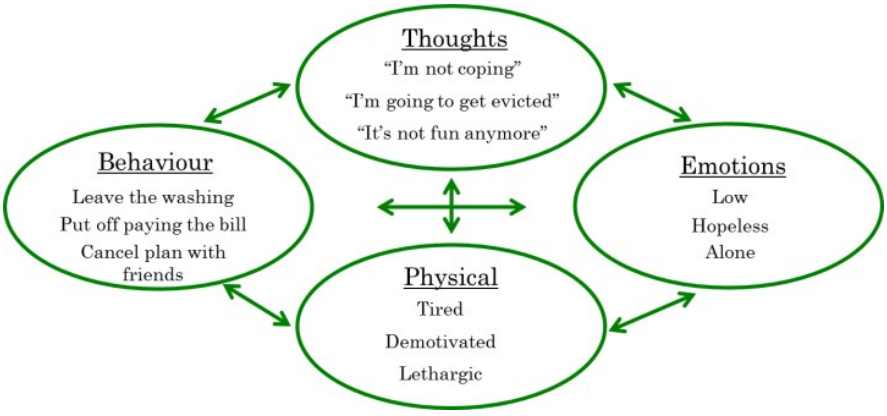
[3]https://www.loc.gov/item/2014588812/.

Figure 8. (Left) *The Point-Milton Keynes Painting*[4]
Figure 9. (Right) *The Point at Night in 2022, After Lily More*[5]



Turning to the social aspect of smart cities, observations of Milton Keynes developments in specific, revealed that there is confusion between offering indoor activities and shaping an experience in city planning using elements of art, nature and architecture to allow people to fulfil the human need to have a varied experience where they can naturally learn, feel, imagine, act, marvel, interact with their surroundings. Another misperception is related to the difference between inspiring people to have reasons to go to the city centre and giving them a motivation that is more emotional as a result of being attached. The connection between offering a good quality design and achieving bet well-being and lifestyle comes more apparent when exploring the low mood cycle shown in Figure 10. As the principle "Action comes before motivation" is used in insight corrections and behavioural activation to maintain good habits, the first is subject to the procrastination and cycle, and the latter breaks it by eliminating the natural waiting to "feel like it" as taking action is faster and powered by inner motivation.

Figure 10. *The Vicious Cycle of Low Mood*[6]



[4]https://tabithamary.co.uk/product/the-point-milton-keynes-buckinghamshire-print/.
[5]https://www.buckinghamshirelive.com/whats-on/whats-on-news/i-visited-milton-keynes-first-6717726.
[6]https://www.talkplus.org.uk/downloads_folder/Behavioural_Activation.pdf.

Moreover, stimulating a variety of senses is proven to be a good mechanism to improve mental health and reduce stress levels, as people with anxiety problems or overwhelmed are advised to use a grounding exercise in which they are instructed to consciously engage with their senses and explore their surroundings. An example of this is the exercise 5-4-3-2-1; a technique to find five things they see, four things they can touch, three things they hear, two things they smell, and one thing they can taste. (Milton Keynes Talking Therapies Service (IAPT))

The Unique Intimacy of the Night Experience

Sense of Smell

Long-term observations revealed that the low density of people on the streets at night in the new city of Milton Keynes is one of the main challenges the city faces including in its central area. This was also noticed in direct observations with little to no people on foot in the city or enjoying the night walk especially as it gets darker. Bus stops were noticed to be located in dark unsafe spots surrounded by bushes or trees where the person will be walking alone with little to no access to help or other people around. This weakens the overall sensation of safety as the urbanist and activist Jane Jacobs` argument using the concept “Eyes on The Street”, as the indirect monitoring or informal surveillance is lost. This is also noticed when people in Milton Keynes also have to walk through underpasses which does not feel safe, especially for female residents or pedestrians. Lighting is another feature noticed to be used unproductively, especially in communicating the celebrated identity of the new city being “Smart”. Hence, the night experience is devoid of inviting features or details, people are barely noticed to be walking or enjoying a walk if at all in Milton Keynes. Feeling intimidated by being forced to look for the nearest underpasses, stressed and feeling unsafe by dark spots, especially at bus stops makes it easier to take unhealthy and unsustainable decisions going to go out for a walk or rather choose to go by car or sometimes leave the area entirely.

Unique features of the night experience also include stimulating sensations of relaxation, intimacy, and reflection. Denying the human mind, body and soul the opportunity to get lost in the details of the night sky, experience, and sensations, and to recognize its uniqueness enjoyably, is another consequence of lopsided designs that focus only on how they look instead of how they will be experienced. Such an approach is detrimental to the quality of life, human well-being, and attitude. On the other hand, appreciating the power of a multisensory approach to architecture encourages a rethinking of how what and when space is experienced to communicate the celebration of our existence. The use of some natural and building elements that make the night experience different can be noticed in some cities with more attention paid to fragrant plants and lighting. The smell of some plants like the night-blooming jasmine or the "night musk" as known in the Arab world (Figure 11) also fulfils air with a unique, light and soothing scent that makes memories of the place and events that it witnessed with you unforgettable.

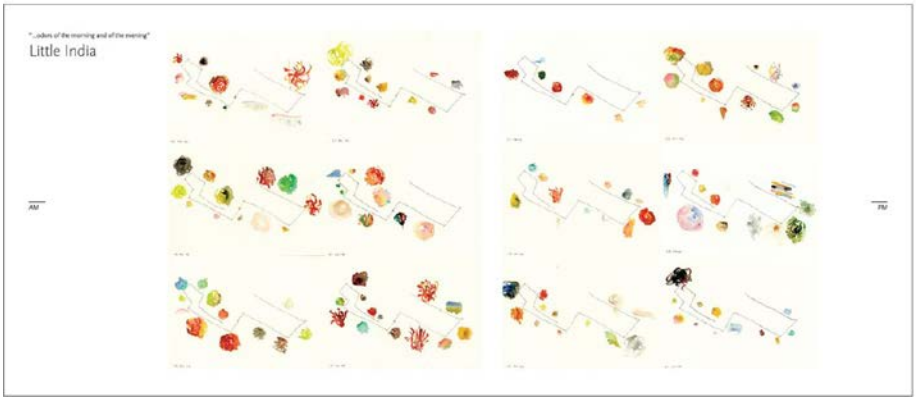
Figure 11. *Night Blooming Jasmine Plant*[7]

The difference between the day and evening smells was noticed more clearly in cities discussed by McLean (2019) using maps of painted representations for scents in Kampong Glam and Little India in 2017 as shown in Figures 12-13. The figures show that in Kampong Glam morning smells (left) with less intense and have shorter longevity than the evening scents (right). Whereas, in Little India, the morning smell scape illustrated on the left side was more intense and longer to last than the evening represented on the right.

Figure 12. *Odours of the Morning and the Evening in Kampong Glam (McLean 2019)*

[7]https://www.burncoose.co.uk/site/plants.cfm?pl_id=1011.

Figure 13. *Odours of the Morning and the Evening in Little India (McLean 2019)*

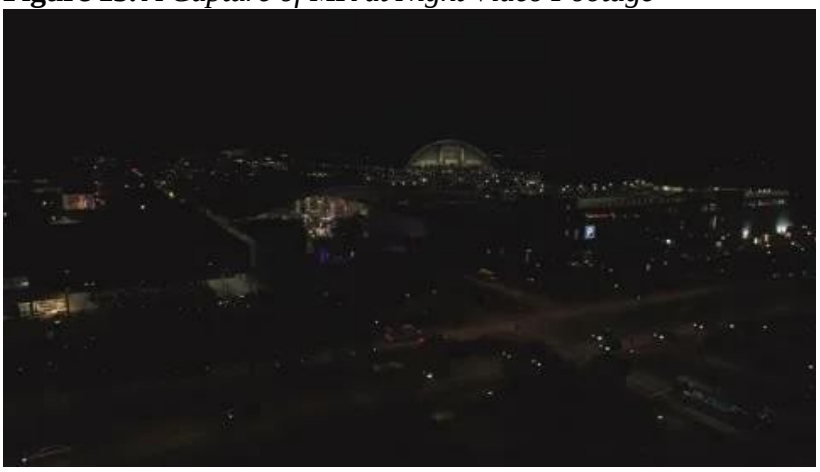


Lighting

Lighting is also another element that comes in handy when setting up a night-time ambience that brings out some of the details, textures, and colours that are sometimes missed during the busy life in the daytime. The case study Milton Keynes shows no strong use or impact involving such elements to stimulate the different senses are examples that show thinking patterns focused on designing cities for namely the day. The original interpretation views for Milton Keynes as designed by the CMK team show a focus on the functional use of light in the city with an emphasis on the station square shown in Figure 14. In addition to Figure 9, more recent night footage of the city is shown in Figure 15, showing the case study investigated as one of the "actually existing smart cities" (Shelton et al. 2015). The capture was taken from a video that can be accessed to explore the current state and sensation of the city and its liveliness at night. Comparing logic and interpretation of design thinking in Milton Keynes and other cities as shown in Figures 14-16 reveals that the focus in the making of the case study was on designing it in the hope that streetlights will illuminate at night, which is a logical is proven not to be enough as Florence Lam, global lighting design lead at Arup confirmed, adding asserts that the way of thinking and the making of public spaces in the city need to change to be done with a careful understanding of how they are used at night and how lighting can affect behaviour. As light is an important aspect of urban design if public spaces are to be used effectively in a 24-hour cycle, the shows how the place as imaged to outdoor spaces at Paddington Central to open to be experienced at night by the practice in 2017 (Wilding 2018).

Figure 14. *CMK Team's Interpretation of Milton Keynes Central Station (Living Archive n.d.)*

Figure 15. *A Capture of MK at Night Video Footage*[8]



[8]https://www.pond5.com/stock-footage/item/133026930- drone-night-footage-milton-keynes.

Figure 16. *Arup's Work in Paddington Central Promoting the Night Economy (Wilding 2018)*

Holding competitions and thought-provoking activities to rethink design and open places at night suggest an emerging mindset to nightlife which is often seen by city authorities as an issue that needed to be managed, as much of the 24-hour cycle is largely viewed in terms of negative outcomes that need to be mitigated through licensing and oversight. Organized by the Mayor of London and the Built Environment Trust, the Night-time is the Right Time competition was looking for suggestions that could help cities function better 24/7 as places to live. Analysing professionals' statements and examples of architecture practices mentioned in Wilding (2018), architects who show an overall tendency to approach nightlife differently attempt to help local authorities to realize the social and economic benefits of a 24-hour city resulting in cities to be increasingly viewing the night as a cultural and financial opportunity rather than an issue. Using technology to better facilitate the capabilities and unique features of design and in turn to enhance the night experience promises of better understanding of the extent to which technology or "Smart" can be utilised instead of merely aimed at. On the other hand, design elements such as lighting were not only overlooked in the case study but also seemed disintegrated or not understood as an effective element that could solve certain issues as one of the effects of the built environment that evidently alters mood, attitude, and behaviour (See more in Webb (2006)).

Figure 17. *The Winning App in Night-time is the Right Time Contest (Wilding 2018)*

The team's Farrells proposal was recognized as the winning idea in the Night-time is the Right Time competition that was held as part of the London Festival of Architecture (Figure 17). The team's idea was to combine technology with architecture as they intended to overcome the difficulties in the London environment to make it more accessible after dark, with better public use of an underutilized urban resource. The senior urban designer at the practice stated that a necessary transformation is needed to change the tendency to think of the night as a time for celebrations, pubs, and bars to be more about making the enjoyment of night-time possible for everyone (Wilding 2018). The team envisioned the capital's waterways as a network of night markets supported by a mobile app that shows the nearest floating facilities (e.g., shops, yoga studios…etc.) With the understanding that the built environment is fundamental to the success of cities' nightlife strategy, the night experience of the city needs these so that possible for it to unravel, some architects realized that commercial pressures meant that places today need to be versatile and usable day and night. A study published by the Greater London Authority (GLA) in 2015 shows that London has lost many of its double-use spaces, in recent years, with more than a third of London's popular music venues closed in the last eight years. The factors attributed to the trend include "planning, licensing, and rising property prices". Orms, the practice behind the St Giles Circus development (Figure 19), for example, designed the venues to be flexible enough to host exhibitions and conferences, with large LED screens to illuminate spaces and accommodate the needs of events such as product launches (Wilding 2018).

Another example of a purposeful coupling of technology and the design of cities at night seems to be present in proposals to make multiuse buildings contribute to the lack of space. Ideas for a flexible building for the Ministry of Sound (Figure 18) in 2015 focused on a 24-hour cycle; as companies like OMA and Casper Mueller Kneer suggested that the shape of the building changes as night comes down. "It's not just a club, it's a radio station, a production company, an events company, so it was easy to understand this new venue as a very multifaceted facility" confirmed the partner Ippolito Pestelini Laparelli. OMA's suggestions for the club hall are made to be flexible, extending usage beyond main Friday and Saturday business hours. Laparelli explained that the idea was is to design it

almost like an experimental theatre space that combines features such as a set of moving stages, moving lights, mechanical partitions and doors with built-in tech that let the space be configured and quickly changed with a single click. Casper Mueller Kneer Architects were motivated by doing something for the community as the Managing Director stated when they suggested "allowing the building to be used for club nights but also concerts, conferences and dance classes", through a series of spaces that could be used not only day and night but also at different times of the week with different configurations. In 2017, the practice also suggested a plan of many "night places" across London, these public spaces are dedicated to running hours a day, promoting a range of after-dark activities that would attract revellers, people working at night and travellers (Wilding 2018).

Figure 18. *Casper Mueller Kneer's Proposal for the Ministry of Sound (Wilding 2018)*

Figure 19. *St Gile at Night Design (Wilding 2018)*

The practice director compared London with Berlin explaining; parks in Berlin remain open all night hosting activities such as movie screenings and hula hoop lessons, as opposed to London's parks which usually close at sunset while proposing to know how to increase access to night-time spaces where people can gather and enjoy while avoiding is the e of the problems. An important element to overcome this challenge is found to be "effective lighting" as Wilding (2018) confirmed. An example of enhancing nightlife activity in cities by using creative lighting ideas is an installation on Barcelona's Plaça de Les Glòries by artec3 Studio and David Torrents which used floor lights to change colours interactively with sounds. Also, artist Debbie Cable in Hull suggested lighting the windows and storefronts of vacant buildings in attractive colourful clusters (Wilding 2018).

Emotional Responses: Safety, Stress and Discomfort

Providing enough room for walking, the connection between buildings and the street, attractive spaces, as well as effective lighting, are recognised as key elements to sensations of safety (Pacheco 2015). However, these elements as discussed previously were not used to create an atmosphere of safety in Milton Keynes, as observations from the field suggest.

Observations of people preferring to walk on the muddy grass edge of the road, make a way through bushes and others killed trying to cross the road at night all show that residents not only find elements like tunnels and underpasses, as shown in Figures 20-21 tiring, forceful and unappealing but also uncomfortable and unsafe.

Figure 20. *Underpasses in Milton Keynes in the Afternoon*

Figure 21. *Homelessness Encountered in Milton Keynes*

These structures were also uncomfortable to interact with as they were occasionally used by homeless people. The logic behind using and continuing to rely on such elements shows a tendency to compromise people's impressions and impact daily encounters with the city elements, as safety is deeply ingrained in our survival mode. Investing time and effort in making an efficient city for cars, rather than securing necessary needs such as feeling reassured, emphasises the lack of design thinking that is selective, cautious and efficient for human well-being in the city atmosphere.

Also, statements and expressions of dissatisfaction were noticed by walkers having to share the same path with scooters, bicycles, and delivery robots as well as other bypasses going in the opposite direction in addition to facing electric scooters left in the middle and at the entrances of red ways even in attractive spots

like Wilen Lake. Old citizens and females often complained about the unsafety of the speed with which these scooters go by with some mentioning situations where they were almost hit by them meeting around blind turns.

Figure 22. (a) *Different Activities Taking Place on the Same Narrow Path*, (b) *Users having to Share Same Path in Wilen Lake*

Figures 22-24 show in comparison the way pedestrians are impacted by wide and marked walkways separating different users and the other narrow paths with more density and varied types of red way users having to share it in and around Wilen Lake for example. The shots in Figure 24 were taken at different spots on the same path going from Willen Lake passing by the Peace Pagoda which illustrated the problematic crowdedness and inconvenience of moving comfortably.

Figure 23. *Different Captures of the same Path going from Wilen Lake and Passing by the Peace Pagoda*

Figure 24. *More Pedestrians Allowed on Wide (Pacheco 2015)*

Another form of uncomfortable sensation in the case study relates strongly to another type of stress which is the stress of boredom. The scientific definition and investigation of boredom indicate that what we aim at should be neither too easy nor too difficult tasks or elements if we are to avoid ending up with a boring experience and instead focus on increasing its quality and value by making them interesting, meaningful and enjoyable (Kubota 2016a, b). Providing a variety of experiences, including physical, sensory, cognitive, psychological and cultural, meets the natural needs of the population to learn, feel, act and interact with their surroundings. "Smart" meaning and progress direction and the resulting impact of the new developments in the case study do not suggest an understanding or acknowledgement of the stress of boredom in cities, streetscapes and buildings designed to meet general functional requirements go against the grain of our inherent, embedded need for novelty and sensuality (Pacheco 2015). Given the powerful effects of architecture and planning, the seamless style in the case study reveals a failure to fulfil claimed potential of a better place as experienced by residents on daily basis. This is because of the associated risks of habitual burnout and depression; as the stress of boredom in cities is not only linked to temporary feelings of discomfort and frustration but also severely affects our well-being as recent studies have found out. Providing a better human experience in the city does not seem to be a top priority as interviews suggest more focus is attributed to what can be modern but also too abstract and which is sometimes devoid of emotional depth and meaning in comparison to approaches of space making (see more in Ellard (2015), Foss (2018), Julier (2020), Pacheco (2015), Salingaros (2011), Wilding (2018)). Observation also shows that the way smart cities are approached does not link conceptions of smart with the communicative and expressive way of designing, locating, and choosing the different elements in streets and parks, which can have a huge impact, if considered and more attention is paid to what it means, how it affects people and to what extent it meets their experiential needs.

The interviews strongly suggest that IT corporates and investors or business

partners are the most likely to reach out, especially when it comes to doing something that promotes the city or certain events like its 50th anniversary.

On the other hand, focusing on marketing and generating profit seems to be restricting other vital links as there is little to no connection or outreach to designers, artists, and professionals that focus on quality instead of quantity in various areas ranging from design to safety (e.g., heritage, art and nature).

Silo working as a phenomenon seems to take another form in some smart cities as the case of Milton Keynes demonstrated through direct observations and interviews. Developing smartphone applications, gadgets and devices appear to be concentrating on efficiently and easily promoting and praising the city agendas being smart in a more way or linear process that misses capturing people`s feedback on the experience with and around the installed technology. The means of communication with the public are almost the same as in other ordinary cities regarding their complaints on some services or technology installed in the city such as electric scooters noticed to be left anywhere as shown in Figure 25 as well as the speed with which the riser passes by pedestrians as they both have to share same paths and red ways. This obstructs the success of the city in engaging the people if it is still drawn back by unappealing routines and time and effort-consuming ways of working. Also, maintaining the cleanness of the city as part of the council's duties to provide a healthy and clean environment seems to be relying more on using machines and workforce as shown in Figure 18, whereas bins and letter baskets were either unavailable or rarely find in different parts of Milton Keynes; which led some people to through or leave a letter behind as observed which in turn sometimes disrupts the experience parks, attraction sites such as the peace pagoda and bus stations.

Figure 25. *Scooters Obstructing Passengers' Paths in Milton Keynes*

Interviewees who were directly involved in developing a smart journey planner to visualize real-time transport data as part of the smart city development programs "Smart Cambridge" and "MK: SMART" stated that one of the challenges facing smart cities is maintaining a balance between competition and collaboration; allowing innovation and producing a variety of creative solutions are necessary to advance. However, investing and appreciating the time consumed in reinventing the wheel or doing things from scratch such as building a city's map, for example, was given as an example to illustrate that it is problematic. The reason behind that as the involved professional explain is that there's a single platform for mapping and travel platforms. CityMapper and Google Maps once downloaded, can be used in all the cities where they exist. This seems also to be consistent with the general tendency of people preferring not to download a different app in every city they go to. Oxford, Cambridge, and Milton Keynes were also used as examples of smart cities competing to some degree. The interviewees asserted that networking events allow Milton Keynes to have conversations with other cities. Remarks were particularly made on doing similar things separately while not knowing they already exist in other cities and or the slowness of the process of reaching out to others as in the case of Oxford, for example, as they are having similar projects and developments going on. On the other hand, trying to build something better than apps like Google maps, for instance, was based on research as interviewees clarified they were interested in making sure target user groups-such as bus users- were using tailored bus apps, as they were urging them to use it, user group, by user group. Professionals involved in doing business model research with a lot of competition talked about another complicated factor to balance which is open data versus closed data. Getting exclusive access to the data for one city allows a product that's better than the leading existing ones like Google; but in Cambridge, for example, the council made sure it's open data, and they have been passed on to Google, making it basic for them to compete against Google, but they also noted that they are aware of the good intentions behind this because of an obligation to deliver something to the citizen.

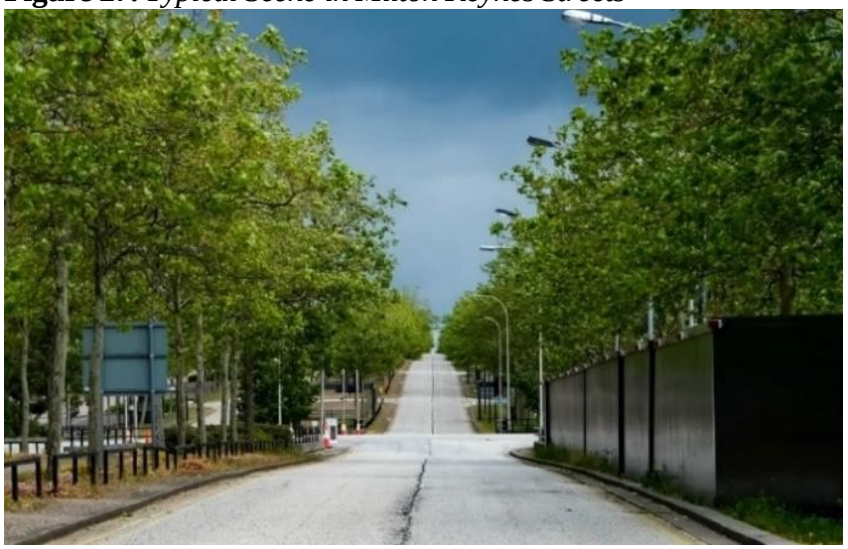
Figure 26. *Using Machines to Maintain Cleanness in Milton Keynes*

The Taste of the City: Character, Wayfinding and Monotony

The lack of character is an impression that seems to be shared amongst people from different backgrounds. In the 1970s, Christopher Booker, founder of Fogeyish Private Eye, called the city "the utterly depersonalised nightmare which haunted Aldous Huxley just 40 short years", while architecture critic Owen Hatherley lately criticised the city for its "bland, kitsch, Thatcherite reality"', and added "Today, Milton Keynes is still the non-place it was planned to be.", and Jackie Kay; Scottish poet, describing it's the characteristics that make it full of paradoxes that she personally likes but adding "its public image is a bit of a joke". Another challenge to the unique image of the city seems to be separating it from a reputation of it being a mere alternative to London or "a London overspill zone" (Jeffries 2017), as stated by interviewees with experts involved in development projects in Milton Keynes. Concrete cows seem to be another controversial part of Milton Keynes's image with comments not only by people on social media channels but also on the official website of the Milton Keynes Gifts and Souvenirs of "Mini Concrete Cows" that belongs to the visitors' information centre: "Milton Keynes has become famous if not infamous for the concrete cows that live in a field in Bancroft", adding that often appeared as "headline news to the national media, keen to brand the city with a rather quirky image"[9]. The concert cows have been kidnapped, held for ransom at times, and placed in somewhat precarious situations, not to mention deliberate vandalism and periodic repainting. Field observations confirm that most of the built areas in Milton Keynes new city are seamless, some buildings look alike and it is hard to recognise where the most functional or public buildings like the train station or the mosques …etc. This weakens not only the skyline or the mental image of the city but also its power to evoke a variety of sensations or attachments, affecting in its turn the well-being of the residents and their motive to take a walk with the stressful sense of boredom (see more in Ellard (2015), Foss (2018), Julier (2006), Pacheco (2015), Salingaros (2011)). There appears a pattern of moving away from the historic or original local sense or identity of Milton Keynes Village, which granted its name to the new city. The American city planning style has dominated the idea of new development with a focus on providing more green spaces instead of living in crowded unclean areas with no access to nature as interviews with long-experienced professionals confirm. Unlike many smart city projects that spoiled the original city with crowded high-rise buildings or skyscrapers, Milton Keynes followed a more horizontal special construction. However, the agenda seems to be revolving around modern development projects apart from heritage, focusing on what is new only and motivated by the reputation and prestige of the Smart City. On the other hand, the new projects and developments show little to no appreciation of the quality of the lived experience, a new hotel tower for example were built blocking the view to Campbell Park (see more in Outhwaite (2021)).

[9]See more in: https://www.cmk.net/mkcows/about.shtml.

Figure 27. *Typical Scene in Milton Keynes Streets*[10]



Also, there is a clear lack of distinct landmarks or characters in different parts of Milton Keynes, while the city increasingly has more roundabouts over time with 130 roundabouts in the last count found on the visitors' information centre; The Destination Milton Keynes Website. This also results in bad consequences on wayfinding and on evoking a mental representation of the city that connects with people as it is easier to be disorientated. The attractiveness and the image of the city are also weakened by not making culture and sensations of attachment readily available on the streets by engaging artistic works. The engagement was obstructed by the type, location and approach of artworks found mostly in some parts of the city, mainly in the central area, as the abstract dominant approach is rare to offer meaningful communication with the viewer especially emotionally or spiritually, leaving people with very little engagement with or to marvel at. Salingaros (2011) confirms that monotony sends alarm signals and makes humans anxious. Since natural environments are fractal, this means that non-fractal organisms stand out and are noted by us (Salingaros 2011). These include purely Platonic figures (cubes, prisms, pyramids, spheres) defining only one scale, which is the largest. Usually, these repeating shapes create the unsatisfying effect of monotonous repetition. Fieldwork and analysis are shown in Figures 27-28 and table 1, confirming that monotony in Milton Keynes is very clear due to repetitious architecture, street elements and planning. The main repetition type is noticed to be horizontal of two dominant types; identical buildings along the streets on the scale of the new city as shown in Figures 29-31, 33-34, Table 1 and identical elements on the scale of the one building's façade as in Figure 27. Such monotonous regularity is perceived by human beings to be alien and reactions are expected to range from boredom to panic (Ellard 2015, Salingaros 2011). In some parts of the city wayfinding and recognition of where one was were extremely hard due to the indistinguishable monotonous surroundings as shown in Figures 29, 34 and 35, leading to feeling lost and confused.

[10]MK Community Hub Social Media Channel: https://www.facebook.com/MKCommunityHub/.

Figure 28. *The View Looking* (a) *to the Right and* (b) *to the Left on the Same Spot in Front of the Shopping Mall the Centre: MK*

(a) (b)

Observations over long time in different areas of Milton Keynes new city, especially the central area established inconvenience for experience of place that is caused sometime by narrow paths and little to no space for pavement, high solid hedgerows used as barriers or fences limiting the ability to view or enjoy cycling or walking activities which affects the experience with a dominant stress of boredom and it detaches the person from the surrounding elements of the city as shown in the shots and illustrations of a sample rout in Enmore Gate, Milton Keynes shown in yellow on the map in figure Similarly, the artistic and psychological consideration, culture or conceptions of participating developers and architects reflects strongly on the quality of provided experience, resulting in compromising the local skyline or identity of the city to overwhelmingly add on skyscrapers in some cases or having areas with split between the new developments and classic and historic designs in others without harmony make the image of the city at its weakest. In addition to the dominance of hedgerows shown in Figures 29-30, other elements used in the new city planning forcing people to go through underpasses as shown in Figures 31-32 disrupt viewing and approaching distinctive buildings, structures or attraction sites if found such as a church with a classic style, Wilen lake Wheel and peace pagoda for instance which makes wayfinding, interaction with surroundings as well as retaining a clear image of a skyline of the city or its parts harder.

Figure 29. *Cycling Routes, Enmore Gate, Captured from Google Maps*[11]

[11]https://goo.gl/maps/ubMUee8DhZDAviG58.

Figure 30. *Captured View of the Cycling Rout in Yellow on the Map, Captured from Google Maps*[12]

Figure 31. *Eye-Level Shots, the View Approaching a Landmark; Willen Lake*

[12]https://goo.gl/maps/zpunbQjucQ15mkpX7.

Figure 32. *Eye-Level Shots, the View Approaching the Landmark of the Peace Pagoda*

Figure 33. (Left) *Eye-Level Shots*, (a) *From Entering the Underpasses*, (b) *the View Walking in Central MiltonKeynes*
Figure 34. (Right) *Identical Scenes*, (a) *Along the Platform in Central Milton Keynes Showing Car Parking*, (b) *Identical ModularBuildings Along the Street*

Table 1. *Seamless Architecture in Milton Keynes*

Figure number	The exterior design of the building	Building Use/Function/address
35		Al-Rawda Mosque, Islamic place of worship and community centre, Milton Keynes central area. *Photo source:* https://www.mkica.org.
36		Milton Keynes Central, Railway Station, Station Square. *Photo source:* https://www.geograph.org.uk.
37		Residential buildings, The Hub Apartments, Milton Keynes hub. *Photo source:* https://www.nationalcorporatehousing.com.
38		Office building, Metropolitan House, 321 Avebury Blvd, photo after Milton Keynes, hub/central area. *Photo source:* https://www.loopnet.com.
39		Commercial (Shops, health club and spa) buildings, 489-499 Avebury Blvd, Milton Keynes central area. *Photo source:* https://www.realla.co.uk.
40		Centre: MK, shopping mall, MiltonKeyes central area
41		MK Gallery, Art gallery, 900 Midsummer Blvd, Milton Keynes.*Photo source:* https://www.destinationmiltonkeynes.co.uk.

Summary and Recommendations

The topic of the paper has been mainly concerned with aspects that are overlooked in the case study as an example of a smart city that is preoccupied with the meaning of progress, smart and development that is exclusive to gadgets, software, and similar advances. Relations to visual language and the role of architecture, mental image, impression and experience of the city were clarified showing how significant to explore in terms of the actual experience of the smart city and what results from it, impacts it and how it is being thought of and appreciated. There are issues encountered in the overall performance, engagement and attachment in the case study that could have been improved through a focus on design elements and elements or characteristics of the city and its planning, yet they are absent in the thinking, planning and implementation. This shows a need to rethink the focus, label meaning and outcome of smart cities. As noticed in comparisons made with the case study, the paper suggested that it helps to consider and integrate approaches that help get more focused on what can be achieved by a healthy more liveable design and environment of the smart city as well, instead of a prestigious smart city that is namely reliable and focused on technology, robotics, infrastructure... etc. This is mainly important given that such thinking and approach is proven to be of practical benefit and experiential fulfilment and significant to the city and its residents.

According to the fieldwork and long experience of living in the case study, the monotony that Milton Keynes suffers as shown in the analysis could be improved through more variations such as of building appearance, landscape elements and character of the place while it best accommodates function, context, and expression of authenticity to encourage higher interactions and attachments. Also, along the street and on the scale of the one façade a variety in colour, lighting, material and pattern, better engages the eye and other senses as they reflect on some taste or ambience and would be greatly beneficial to break boredom and repetition that overlook function, location, human needs and nature. Furthermore, prioritising quantity over quality has been proven to have little impact on well-being, and sometimes negative outcomes. For instance, the trees as a natural element of the city have been used in a similar repetitive monotony along all streets and the streets ended with nothing to look forward to. Thus, it is not only that the city is green in numbers or areas that only counts, but also how its landscape contributes and integrates concepts and tools of engaging planning of the smart city that further focuses on the experience and impact instead of numbers and grids (often thought of in two-dimensional map or way of imagining the city). Having a heart in the smart city needs to be better understood and realised by different means not including various elements of design, nature and activities. Making the city needs to be considerate of it at night and not only in the daytime. The uniqueness of the night, its atmosphere, and its role in evoking mental images and attachments have been explored in the paper giving examples of lighting, landmarks, and natural elements that give scents at night and were all implemented in other cities or approaches proving its power to elevate the quality of experience on the ground. Adopting such thinking patterns, understanding and appreciation of

the “city” element of the “Smart City” label is important not to be compromised for focus on certain aspects such as technology or essential services to exclusively limit what “Smart” could mean. This is also significant given that many scholars have been invited to focus on what is practically achieved and realised instead of the label and vision claim in terms of the smart city being more successful, liveable, and sustainable.

As this paper discussed design elements, from artistic and architectural experience and background, supported by various studies, illustrations were made throughout the paper on how the built environment imposes vital responses in terms of comfort and safety, showing clear examples noticed to be disadvantaged in a way that causes unpleasant experiences. Field observation supported by comparisons and direct long experience living in the city and illustrations were provided with examples of unpleasant feelings generated by lacking “eyes on the street”, the low capacity to accommodate multiple groups and uses or user types or limitation of choice. This highlights a need not only to monitor statistics of safety or crime considered as the measure or goal for cities vision or agenda but also the sensations of being free of fear, distress or coercion to uncomfortable choices, encounters or characteristics, like that caused by certain designs, compositions, or consequences of decisions about the built environment, planning style or approach.

The vision of smart cities and the case study explored, claim to be a better and more liveable better city than non- smart, on the other hand, the investigation of shared understanding, or patterns amongst stakeholders, interviewees, and city elements on the field revealed issues while having a concerning level of overlooking design elements that could have helped solve them. For instance, Milton Keynes suffers low intensity of people on the street, walking and particularly at night. When stakeholders discuss this, they seem to focus on certain developments and are more likely to think of phone apps, infrastructure, high tech or similar means to hold the answer or the solution to problems, whereas seeing through a lens of design and a reflexive research approach, it was clear how other tools and techniques could help reduce how plain-and sometimes dark-the city generally is. Comparisons show that also the focus is on functional lighting if found, whereas other cities or designs successfully recognised how significant and interesting lighting can be and that a well-lit city can have many benefits if designed to encourage people to do something, to be there and to enjoy its atmosphere. Design elements such as lighting were not only overlooked in the case study but also seemed disintegrated or not understood as an effective element that could solve certain issues as one of the effects of the built environment that evidently alters mood, attitude, and behaviour. Those who are responsible or excel at shaping human experience, designing, or communicating the ambience or taste of the city through perception and emotional response also seem to be detached from thinking of them as a crucial party to take part in finding solutions to the performance of the city. On the other hand, people who mostly were noticed to be in the group of stakeholders or circle of "experts" tend to be from regulations, information and communication, technology, transport and other essential infrastructure and services.

By learning from the differences explored in the analysis and comparison with other cities designed using multifunctional spaces, the benefits are noted to be significantly noticed in more people engaged, using the spaces at night, boosting not only the sense of attachment and safety at night but also the city's economy and long-term sustainability. In cases where there is not enough space, adopting this approach has shown a purposeful coupling of technology and the design of cities at night, which can inspire and reduce the separation or gap in thinking and making of cities between the two parts of the "Smart City" label to produce beneficial outcomes for the residents.

Conclusion

The paper engaged with one of the existing smart cities to illustrate how important is to consider the way the focus on technology in smart cities and a certain meaning of progress is affecting other aspects of the city, especially in terms of human sensations and needs. Most of the interviewees agreed on common issues with the label of "Smart Cities", the literature and practice of space and city-making emphasized the need for vocabulary or language that is better capable of shaping and delivering atmospheric qualities and good quality human experience. The role of architecture has been noticed to be misunderstood and separated from Smart, even though, as this paper tried to argue, the design of the built environment affects the overall impression, performance and power of the city. The relationship between the Meaning of Smart and the impact on the Mental Image of the City as explored in the case study has been illustrated with the help of visual comparisons. These comparisons and arguments showed the effect of what has been lost or compromised. Having a memorable image of the city, its ambience, uniqueness and character not only show significance to human wellbeing in terms of having a rich, well-balanced experience in the city but also in encouraging more people to enjoy a night walk, for example, which intensifies the feeling of safety for residents. Also, the paper presented ways to enhance the qualities of the night experience, with examples from other cities and initiatives. Given the nature of the topic, explaining the lived experience in the city, the paper illustrated the emotional responses and impressions of the city, clarifying how certain overlooked aspects resulted in sensations of safety, stress and discomfort, as well as traces of what is unique about the case study and what strengthened or weakened the taste of the city: character, wayfinding and monotony. To assume that enhancing the efficiency of basic services in the city such as transportation and food delivery is enough for it to be recognized better in everything under the label of Smart City is of great impact on the development of those aspects that are important for the resident, Therefore, the ways of thinking of Smart and construction of smart cities are expected to be of better authentic potential to deliver a better experience when the social aspect is better integrated and not overlooked. Interviews strongly suggest that IT companies and investors or business partners are the most likely to be involved in the development of the case study as the experts or main stakeholders with a focus on marketing and revenue generation. Unfortunately, this seems to

limit other important connections as there is no emphasis on the actual experience enhancement concerning quality over quantity in various areas related to design (e.g., heritage, art, wayfinding and lighting) and emotional feelings and impressions of the city affecting the level of comfort and safety felt for example. In turn, this impacts the level of participation and attachment to the city, and the decision taken by residents on staying in or moving out. The themes presented in the paper showed examples of other practices and approaches paying attention to the aspects found to be overlooked in the case study as a smart city, revealing that the economic and social benefits are practical and significant.

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