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Exploring the Potential of Recycled Aggregates in Modern Construction Challenges and Innovations

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Keywords— Construction Materials, Natural Aggregates, Sustainable Alternatives, Recycled Aggregates.

Abstract— The reliance of the construction industry reliance on natural aggregates has led to significant environmental concerns, including resource depletion and habitat destruction. This paper explores the potential of recycled aggregates as sustainable alternatives to natural materials, emphasizing their environmental and economic benefits. It provides a comprehensive review of various types of recycled aggregates, their extraction processes, associated challenges, and recent innovations to improve their applicability. Key findings highlight the effectiveness of advanced treatment techniques and material modifications in enhancing the performance of recycled aggregates. The paper concludes with recommendations for future research and standardization efforts, aiming to integrate recycled aggregates into mainstream construction and contribute to a more sustainable built environment.

I. INTRODUCTION

The worldwide building sector has been acknowledged for a time as a major user of natural resources. Aggregates, like sand and crushed stone play roles in the creation of concrete and asphalt. [1,2]. Nevertheless, the continuous utilization of these resources has resulted in notable environmental issues such as habitat loss and water contamination along with the exhaustion of natural reserves, leading to a surge in interest towards sustainable building methods in recent times [3,4].

Government rules and policies encourage the usage of eco friendly materials in building projects within the ASEAN region. ASEAN's governments plan to boost this construction methods by providing financial aid for using environmentally friendly materials such as supplementary cementitious materials (SCMs) and recycled aggregates. The goal of these efforts is to decrease non-renewable resource usage and waste generation while also lessening harm to the environment and simultaneously support sustainable economic growth and social welfare in the long run [5].

The market size of the construction and demolition sector reached \$100.5 billion in 2022. It is anticipated that this industry will expand from \$105.72 billion, in 2023 to \$158.60 billion by 2032 showing a compound growth rate (CAGR) of 5.20% between the years 2023 and 2032. Factors such, as urbanization population increase and infrastructure investments are driving market growth significantly [6].

Recycled materials have become a choice, for infrastructure development bringing both environmental and economic advantages. The uses of these materials in construction are wide ranging from incorporating them into production to building roads and more. One key application is using recycled materials to make concrete. Research indicates that these materials can substitute ones in mixes leading to a notable decrease, in the environmental effects of making concrete. This switch not helps preserve resources but also lessens the carbon footprint related to extracting and processing new materials [7,8].



Fig.1. Forecast of market size of the construction and demolition sector [6].

Recycled aggregates are utilized alongside concrete, in road construction in the layers of roads. These materials offer strength and longevity. This application is particularly beneficial in urban areas where construction and demolition waste is abundant aiding in waste disposal and lessening the demand, for landfill space [9,10]. Recycled materials are also used in building embankments and retaining walls. Incorporating them into these structures can enhance stability minimize erosion risks and offer an eco substitute, for materials [11]. Recycled aggregates are also suitable, for making items precaste concrete such as blocks and pavers which play a crucial role in urban infrastructure [12]. Furthermore, incorporating recycled aggregates, into concrete can improve characteristics like insulation and sound absorption making it ideal, for a range of construction purposes [13]. Moreover incorporating recycled aggregates, in road building can result in reduced costs since they are typically more economical, than aggregates [14].

The analysis of chemicals showed that all the recycled aggregates tested (recycled concrete aggregate (RA-Con), recycled ceramic aggregate (RA-Cer), and mixed recycled aggregate (RA-Mix) did not have any substances surpassing the specified limits set by regulations confirming their suitability, for being used as construction materials [15].

II. TYPES OF RECYCLED AGGREGATES

Recycled materials come from origins each adding distinct features to the properties of the material. It is essential to comprehend these origins to evaluate the possibilities and constraints of using recycled materials, in construction. The main origins consist of waste from construction and demolition by products, from industries and reused asphalt pavement. In the construction sector used recycled materials include recycled Concrete aggregates (RCA) recycled masonry aggregates (RMA) mixed recycled aggregates (MRA) and reclaimed asphalt pavement (RAP) [16]. (Pereira & Vieira, 2022).

III. EXTRACTION OF RECYCLED AGGREGATES

There are few ways of past researchers extracting the reycled aggregates from demolition site. Generally, the whole process of extracting recycled aggregate involves sorting and segregating the waste materials, crushing and screening aggregates and lastly testing the quality of the recycled aggregates [17].

The process starts by gathering and choosing CDW materials, which are then tested in ways to confirm they meet the required standards. These tests cover aspects such, as composition, particle sizes, density, water absorption, shape and also include checks for pollutants [18]. Once the suitability of the CDW is confirmed the next phase includes treating the waste to generate RA. This can be done using techniques, like the two stages jigging process, which efficiently isolates impurities such, as ceramics and mortar thus improving the grade of the RA [19]. Moreover, by utilizing materials and implementing pretreatment methods it is possible to enhance the characteristics of recycled aggregates (RA) thereby improving its ease of use, strength and longevity for structural purposes. It is advised to follow a revised mixing method and determine the levels of replacing cementitious materials to attain the desired quality in concrete [20].

IV. PAST RESEARCH

The studys results show that the production of mixed recycled aggregate (MRA), from construction and demolition waste leads to a 70.66% reduction in environmental effects compared to the production natural aggregates obtained from a quarry. Furthermore, the economic assessment showed that production of recycled aggregates costs 30% less than using natural aggregates. The procedure of this research adhered to the four stages detailed in the ISO 14040;2021 encompassing Goal and Scope of the Study, Life Cycle Inventory, Impact Assessment, and Interpretation [7].

Reactive areas are a place that characterized by soil that undergoes volume changes in response to moisture fluctuations. Therefore, it causes a challenge for installing infrastructure such as pipelines and buildings in this area. The research evaluated the effectiveness of using recycled materials to stabilize soil zones by examining changes in ground deformation over time. The research employed InSAR methods to observe changes, in the ground of a sewer pipeline trench filled with recycled materials, in Melbourne, Australia between October 2020 to February 2022 (17 months). The test reported that although not eliminating the movement entirely, the recycled materials helped in stabilizing the ground by reducing the extent of movements [13].

By utilizing 25% of incinerated ash (IBA) and adding 40% copper slag, the strength of high-performance concrete (HPC) can be boosted. Moreover, incorporating recycled coarse aggregate (RCA) in self compacting HPC allows for

replacing up to half of the aggregate without compromising durability characteristics [10].

V. CHALLENGES

Recycled aggregates, despite their sustainability benefits, face numerous challenges that hinder their widespread adoption. These challenges include variability in quality, mechanical performance limitations, and a lack of standardized testing procedures. Addressing these issues requires.

Table 1 summarizes each challenges faced by different types of recycled aggregates and limitations respectively.

Type of Recycle Aggregate	Limitation	Author
Recycled Concrete Aggregates (RCA)	The paper mentions that recycled aggregates may exhibit slightly inferior characteristics compared to natural aggregates in terms of porosity, friability, and variability, indicating a limitation in the quality of recycled materials. It is highlighted that there is currently no specific standard for measuring the water absorption of recycled aggregates, which poses a limitation in accurately assessing this important property. The use of recycled aggregates in concrete results in a significant drop in compressive strength compared to control concrete without recycled aggregates.	[21]
Recycled Construction and Demolition waste (CDW	(CDW) as aggregates, in making concrete resulted in water absorption and apparent porosity along with density and mechanical strength (such as compressive strength and tensile splitting strength). The research emphasized that the irregular shapes and fragile particles of CDW materials like ceramics, concrete, mortar, among others weakened the concretes durability.	[22]
RCA	A key issue revolves around the inconsistency in the quality of reused materials impacting the effectiveness of the end result. This inconsistency typically arises from the composition of construction and demolition debris, which may comprise materials like concrete, bricks and asphalt	[23]
RCA	Incorporating recycled aggregates in concrete production reduces the Life Cycle Cost (LCC) compared to using natural aggregates.	[24]
Recycled Construction and Demolition waste (CDW)	The physical and chemical characteristics of recycled aggregates, from construction and demolition waste varied from each other resulting in a challenge that restricts their application in producing construction materials. A notable drawback in the manufacturing process is the abundance of fines in the recycled aggregates resulting in a high modulus of fineness that influences the aggregate properties.	[15]

Table.1: Limitation of Different Types of Recycled Agrregates

VI. INNOVATION

In order to tackle this problem, it is essential to conduct a quality control procedures and conduct standardized testing procedure to ensure the reliability of recycled aggregates for construction purposes [25]

The research discovered that Recycled Aggregate Concrete (RAC) exhibits lower strength levels than Natural Aggregate Concrete (NAC). However, by substituting only 40% of aggregate, percentage replacement that have been identified as the optimal replacement percentage that maintains strength. Furthermore, introducing either 1.5% of Polypropylene (PP) fiber or 1.25% of recycled PP fiber into RAC enhances its performance and achieves optimal strength levels. Polypropylene (PP) fibers are one of the cheapest fibers compared to other fibers such as steel, glass, and synthetics and are also widely available [24].

The research papers findings suggest that incorporating crushed old concrete (COC) as recycled fine

aggregate (RFA) in polymer reactive powder concrete (PRPC) can improve the tensile and flexural strengths of the concrete. The research indicates that the mixture containing 40% COC replacing aggregate (NFA) demonstrates the highest levels of compressive strength, tensile strength and flexural strength both before and after exposure to various liquids, like water, fresh oil and used engine oil [9].

Using recycled aggregates, in infrastructure construction has proven to be effective because they can maintain fracture characteristics and performance, as regular concrete when combined with steel fibers. The studys results suggest that steel fiber reinforced concrete made with recycled aggregate exhibited performance and fracture characteristics to concrete. Additionally, it displayed enhanced fracture properties. Decreased brittleness as the steel fiber content increased [11].

The research papers findings suggest that when the recycled brick aggregate (RBA) replacement rate increases, the strength of RBA decreases. However, this decrease can be effectively countered by incorporating polypropylene fiber (PPF) and nano silica (NS) into the mix (PPF NS). The study revealed that PPF NS concretes frost resistance compared to concrete as indicated by improved visible characteristics, reduced mass loss and strength preservation following freeze thaw cycles. Moreover the microstructure of PPF NS modified RBA concrete was denser, with a fractal dimension in its cross section both before and, after freeze thaw cycles [12].

Recycled materials, like recycled aggregates (CRAs) and processed recycled aggregates (PCRAs) have shown potential in improving the longevity of alkali activated concrete (AAC) for sustainable infrastructure. The research revealed that AAC experienced an increase in strength reaching 65.9 MPa after being exposed to seawater for 90 days demonstrating durability. Examination of the microstructure and after durability tests indicated that AAC with PCRAs displayed polymerization due, to a higher

presence of alumino silicate gel leading to improved performance [25].

Recycled concrete aggregates (RCAs) are commonly obtained from construction and demolition waste helping to reduce waste in the industry. Utilizing coarse recycled aggregates (CRCA) is essential, for creating eco concrete. Their role in the construction field is significant as they provide an alternative to aggregates contributing to waste reduction and environmental sustainability efforts. However, the effectiveness of CRCA in concrete may decline when higher replacement rates are used due to the presence of mortar. Implementing treatments such as washing, drying and carbonation can alleviate these drawbacks highlighting CRCAs importance as an asset, for the construction industry [26].

In the research adding recycled aggregate (RCA) to asphalt mixes showed great improvement of properties when combined with waste alumina. This method not efficient to handle waste management concerns but also boosts the overall performance of asphalt mixtures. Replacing 20% of conventional filler with secondary aluminum dross (SAD) in the mixture containing recycled concrete aggregate (RCA) at different rates improved the tensile strength ratio (TSR) by 8.52% and the index of retained strength (IRS) by 13.42%. Optimal resistance to moisture damage was achieved with a 25% RCA content in the mixture. Treating the RCA with acid resulted in increased stability by an average of 5.8 and reduced Marshall flow by 3 [14].

Ferrández et al.,(2023) introducing 2 steps of treating the recycled aggregate which are Washing and Secondary Crushing. The objectives of washing stage are reducing fine and impurities content, and also reducing the water absorption coefficient. The Secondary Crushing stage on the other hand was introduced to increase the amount of material recovery.



Figure 2. Manufacturing system of Recycled Aggregates with the addition of the secondary crushing and sand washing stages [17].

Although the quality of treated recycled aggregate still inferior compared to natural aggregate, the results of introducing of these two (2) stages still led to satisfactory results ; the compressive strength and flexural strength of end product which was mortar shows improvement compared to the end product that are incorporating untreated aggregate. Flexural strength of final product increased by 5% while compressive strength increased by 6% when the treated aggregates were incorporated compared to when untreated aggregates were used [17].

VII. CONCLUSION

Recycled aggregates offer diverse potential for promoting sustainability in construction by addressing environmental challenges like resource depletion and waste management. Despite challenges such as inconsistent quality and lower mechanical performance, innovations in treatment and innovative material combinations have demonstrated promising results.

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Numerical modeling of artificial egg incubator efficiency

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Abstract— In summary, this work presented the essential points enabling the process of operating the artificial incubator, having sought to establish the link between theory and reality, the experimental phase was tackled. This involved manipulating the prototype artificial incubator materialized in the mechanical workshop of the Institut Supérieur de Techniques Appliquées de Kinshasa. The Matlab software was used to run simulations which produced results showing the variation in egg hatching rate as a function of temperature, the variation in internal temperature as a function of the incubator's external temperature, and the variation in humidity as a function of time (days). The results found were discussed with those found by other researchers.

I. INTRODUCTION

Thanks to its nutritional properties, chicken meat is becoming a necessary commodity for humans and many other living species. To obtain it in a renewable way, we resort to the production of chicks, an operation that requires the presence of a broody hen. Increased consumption of chicken meat is proving insufficient to meet the needs of the entire population, as it is difficult for a hen to incubate more than a hundred eggs in a day. To maximize chick production, scientific investigations are in full swing and technologies are being developed to make the process of profitability easier. To this end, researchers have produced the so-called artificial egg incubator, at device designed to hatch eggs under at synthetic influence that approximates natural incubation. A number of studies have shown that the choice between a natural and an artificial incubator depends on the number of chicks the user intends to raise at the same time, the work involved, the operating costs of an incubator, and the results and quality of the incubation products [1]. With this in mind, we turned our attention to numerical modeling of the efficiency of artificial egg incubators. Since the artificial incubator allows the hatching of a quantity of eggs laid, it facilitates the production of a high rate of chicks that are viable at the lowest cost. The efficiency of an incubator is based on its ability to regulate heat, humidity, ventilation and egg rotation to ensure normal embryonic development [2]. While the materialization of these skills can only take place if there is optimization of the variation of the egg hatching rate as a function of temperature, variation of the internal temperature of the function, of the external temperature of the incubator, of the variation of humidity as a function of time. We therefore decided to carry out this study with the aim of determining the efficiency of the artificial incubator before the egg is introduced into it.

II. MATERIALS AND METHODS

The methodological approach consisted in analyzing concrete situations, and obtaining information from various groups of people and documents containing useful information on the subject. This led us to visit the DAIPN farm in Kinshasa and to handle the prototype artificial incubator produced in the mechanical workshop of the Institut Supérieur de Techniques Appliquées in Kinshasa. We also consulted documents containing information relating to our object of study. For the simulation, we used Matrix Laboratory (MatLab) software.

III. INCUBATOR OPERATING PROCESSES

3.1 Egg processing

To achieve efficient and profitable operation of the incubator, the following steps must be taken into account:

- ➢ Egg selection;
- ➢ Egg cleaning;
- Storage;
- ➢ Incubation [3], [4].

3.1.1. Egg selection

To make a good selection, you need to know that egg weights are not identical. It varies from breed to breed, from thirty to seventy grams. The best results are obtained with eggs from good layers of normal size. These eggs must be fertilized before being placed in the incubator for incubation. A rooster can fertilize several hens. Effective results are obtained with one cock for every ten hens, but for heavy breeds, the number of hens must be reduced. After mating, the hen lays the fertilized eggs for at least eight days.

The shape of the egg must be taken into account, as a malformed egg is not suitable for incubation if good results are to be achieved. The quality of the shell itself is very important for good selection. If the shell is cracked, the egg is dehydrated. If the egg is dehydrated, it produces a stillborn or very weak chick.

3.1.2. Egg cleaning

The choice of eggs is a crucial step in the incubation process. After selecting clean, well-shaped eggs, they are cleaned using a clean, dry cloth. This is a very dextrous process, given that the egg is a very fragile body, liable to break at any moment.

The eggshell is porous, allowing dirt, bacteria, water and air - the list goes on. Hence the need to avoid using water to clean eggs, as it opens the pores in the shell, weakening incubation results. Water is not the only solution to avoid if you want to produce chicks of the right quality. If a solution is used to remove dirt, it will not only remove the dirt but also the outer cuticle of the egg, exposing it to bacteriological contamination. But if we're dealing with very dirty eggs, they should be brushed in water at a temperature higher than that of the egg (40°C). A disinfectant such as sodium hypochlorite (NaClO) can be added to get rid of pathogenic germs.

Eggs should be collected using a non-porous or easilycleaned plastic tray, to avoid contamination or transmission of bacteria.

3.1.3. Egg storage

Once eggs have been collected and cleaned, the question remains as to where they should be placed for storage while awaiting incubation. It is advisable to place selected and cleaned eggs in at cool place at room temperature. Eggs destined for incubation should be collected and placed under cover as soon as possible. The ideal temperature for storing eggs is 25°C and the ideal relative humidity is 75%. High humidity is evidenced by the appearance of microscopic fungi called molds, which form branched vegetations on the surface of organic matter. Mouldy eggs should be discarded and not used for incubation. Most species tolerate at 14-day storage period before the hatching rate is affected. During this stage, egg turning is also essential for a high hatching rate.

3.1.4 Egg incubation

Egg incubation is the final and crucial step in determining whether the previous steps have been carried out correctly. It is after this stage that we will obtain the desired results or not. To achieve favorable results, a few parameters must be respected. The parameters determining results are: temperature; humidity; ventilation; egg turning; egg candling. As a result, the following boundary conditions need to be determined:

4. Numerical simulation

We carried out the numerical simulation using the data below, representing the above-mentioned boundary condition, implemented by running the program in Matlab software.

Data to be simulated

- Variation in temperature inside the incubator: 0 to 45°C;
- Temperature variation outside the incubator: 0 to 60°C;
- Variation in humidity inside the incubator: 0 to 80%;
- Variation in egg hatching rate: 0 to 100%;
- Variation in incubation time: 0 to 30 days.



IV. RESULTS AND INTERPRETATION

Fig.1: Variation in internal temperature as a function of external temperature.

Figure 1 shows the variation in internal temperature as a function of the incubator's external temperature. The internal temperature rises from 0 to 40° C, while the external

temperature rises from 0 to 50° C. This proves that our incubator is working properly.



Fig.2: Variation in egg hatch rate as a function of temperature

Figure 2 illustrates the variation in egg hatching rate as a function of temperature. It can be seen that the hatching rate varied from 0 to 90%. While the temperature varied from

30 to 45°C. This variation in the curve attests to the reliability of our incubator.



Fig.3: Humidity variation as a function of time.

Figure 3 shows how humidity varies with time. It can be seen that when the eggs hatch, the incubator does not maintain the same percentage of humidity, because at each stage, the incubated eggs need a well-defined degree of humidity. In order to achieve satisfactory results, compliance with the required humidity level for incubated eggs during hatching is more than a requirement. It should be noted that during the first week of incubation, the required relative humidity is 60%, at the beginning of the third week, the relative humidity is 50% and a few days later, i.e. before hatching, the humidity level needs to vary to 70%. From day 19, eggs can be gently moistened with a damp cotton cloth to soften the shell and help the chicks to hatch.

V. DISCUSSION

This study produced results defining the variation of internal temperature as a function of external temperature, ranging from 0 to 40°C for internal temperature and 0 to 50% for external temperature. In this respect, at number of research studies point out that if the outside temperature is below 30°C, the incubator will have to work hard to provide an adequate temperature for the incubated eggs. But if the outside temperature is above 40°C, the incubator will work to maintain the inside temperature at a range of 37 to 39°C, confirming the efficiency of our incubator [5],[6].

With regard to the variation in egg hatch rate as a function of temperature, the variation ranged from 0 to 90% for hatch rate and from 30 to 45°C for temperature. Comparing our results with those reported by Wageningen et al, Pelé, Eekeren et al, Azeroul [7],[8] [9],[10] who report that the

at a range of ur incubator as a function to 90% for e. Comparing n et al, Pelé, port that the [13], SHAYMAA A. humidity in the incuba varies respectively from acceptable for proper humidity values, we f those found by the above

hatching rate in an incubator can vary from 50 to 70%, 70 to 90%, 65 to 70% and 87%. It is worth noting that our incubator's hatching rate is close to those of PELE B. and AZEROULE. In addition to these findings, there are those of WAGENINGEN et al and EEKEREN N.V et al. which fall within the range of our incubator hatching rate results. As for incubator temperature, the variation is from 30 to 45°C. ELBACHIR MOHAMMED et al [11] found that at temperatures below 35°C to above 40°C, the hatching rate was zero. A good percentage of hatchings occur in the 37°C to 39°C temperature range. On the same subject, MUKHTAR IBRAHIM B. et al [12] point out that incubation temperature variation curves on day 1 and day 10 remain very similar and uniform, with the following respective minimum and maximum values: day 1 (37 to 40°C and 37 to 78°C) and day 10 (37 to 45°C and 37 to 73°C). With the same daily average ranging from 37 to 59°C. Tackling this question with the same logic as MUKHTAR IBRAHIM B. et al. after analysis we find that the average of our temperature results is 37°C. This proves the reliability of our incubator. As for humidity variation with time (Days), the required humidity is 60% at the beginning of the third week, relative humidity varies from 50% to a few days before hatching, humidity varies once again to 70% at day 19. This is why SUSMITA M. et al [13], SHAYMAA A. et al [14], maintain that relative humidity in the incubator and in the ambient environment varies respectively from 54 to 56% and from 70 to 76%, with averages of 55.08 to 71.2%. These values are acceptable for proper incubator operation. Looking at our humidity values, we find that they are within the range of those found by the above-mentioned researchers.

VI. CONCLUSION

Here we are at the end of this work, which has shown just how essential the development of innovative technologies in poultry farming is to optimize the breeding and rearing process. We have highlighted the operating process of the artificial incubator, which requires eggs to be processed through selection, cleaning, conservation and incubation. To scientifically prove the efficiency of our artificial incubator, a boundary condition was established, whereby the results determining the variation of egg hatching rate as a function of temperature, the variation of internal temperature as a function of external incubator temperature, Variation of humidity as a function of time. This set of results attests to the cost-effectiveness of our artificial incubator model.

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Food and Beverage Establishment in Post-Pandemic: Business Design and Customer Satisfaction

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Keywords— Food and Beverage Establishment, Business Design, Customer Satisfaction, Post-Pandemic Abstract— This study discovers the business strategies food and beverage businesses use in Nueva Ecija to satisfy customers postpandemic. With the profound changes in consumer behavior and expectations, while experiencing the pandemic, several establishments would need to adapt their operation and marketing strategies to address shifting customer necessities. The study found that the essential approach was to introduce upgraded health and safety protocols and expand capacity in service delivery. Providing a safe and clean location has become one of the most critical aspects of customer visits. This will instill more trust in the customers' minds, considering responsibly checking everything daily regarding regular sanitization and general cleanliness, as well as compliance with other health protocols and an extremely high standard of hygiene. This, along with good queue and wait time management and contactless methods of payment, will also improve the experience. Business strategies are also changing in response to changes in customer behavior, and digitalization marketing is evolving. Additionally, targeted promotions, discounts, and loyalty programs well-suited for a post-pandemic world enhanced customer retention and satisfaction. In addition, relationships between customers and establishments were improved through personalized marketing campaigns, more transparent communication, and security measures. Improving service delivery has also been critical to customer satisfaction. Those who retrained their staff to operate in the post-pandemic period improved service quality significantly.

I. BACKGROUND OF THE STUDY

Most food and beverage establishments had to put in place robust health and safety measures to win the trust of their customers. According to Gössling et al. In addition, the importance of observance of such protocols, as highlighted in Emery (2020), is not only to retain consumers and encourage new ones to enter but also to win back their confidence and safety. In addition, Shin and Kang (2020) also exemplified that properly communicating these health measures resulted in high customer satisfaction. Restaurants communicating their COVID safety practices well could retain customers and attract their fair share of new ones in the post-pandemic world. The study also points out that changing service delivery models to fit new consumer attitudes is another crucial strategy. Jiang and Wen (2020) highlighted that cleanliness and maintenance link directly to customer satisfaction in the F&B industry. Coming out of the pandemic, firms that competed on these features and efficiency delivered higher levels of customer satisfaction. Gallegos (2024) also observed this trend and added that combining digital technology, such as mobile or contactless payment systems, greatly enhanced customer experience and enjoyment.

Marketing techniques, too, transformed post-pandemic and targeted customer involvement in the digital realm. Must use platforms like Instagram, Facebook, and Twitter to boost customer engagement in the F&B sector (International Airport Review, 2024). This was important as it helped retain and attract customers, who would get coupon codes, discounts, and unique campaign messages, always making them feel more valued and connected to the brand. These measures were incredibly impactful in mitigating customer's increased focus on health and safety post-pandemic.

Staff engagement and training also topped the study regarding what was important to customers. Fansa (2024), for example, argues that exceptionally well-trained employees stand out in customer satisfaction by providing outstanding service. At the same time, excellence in services and a heightened level of customer satisfaction followed from investments made by several establishments, especially in post-pandemic operational procedures (which included staff training). The necessity of queue management to improve customer service is cited in this article. (Food and Beverage Operations: Management & Definitions, n. d.)

To sum it all up, the Food and Beverage industry of Nueva Ecija post-pandemic shows how they have built resilience by adopting customer-centric strategies that put a premium on health safety standards, service quality, and online engagement. Those tactics promoted customer experience and put these businesses in place for long-term repeatable success. With consumer expectations in the Food and Beverage industry developing so rapidly, Food and Beverage businesses need to adapt quickly and flexibly, constantly tweaking their strategies as they discover the needs of the new post-pandemic market. This suggested that maintaining high customer satisfaction levels with this strategy is essential (Heung et al., 2010) in view of the region's profitable F&B industry growth potential and success scenario.

Objectives

1. To determine the demographic profile of the food and beverage establishment in post-pandemic.

2. To determine how many businesses design based on customer satisfaction in the food and beverage establishment are described post-pandemic.

3. To determine the metrics of Customer Satisfaction.

4. To determine outcomes and development plans for the food and beverage establishment in post-pandemic.

II. METHODOLOGY

This study utilized a descriptive comparative research design to analyze the business strategies of food and beverage establishments from Nueva Ecija, focusing on customer satisfaction post-pandemic. This design aimed to connect changes in customer behavior with the business response to provide detailed insights on how operational changes (e.g., health protocols, improvements in service delivery, and the use of digital tools) translated into improved or decreased overall category satisfaction from a customer perspective. The research spanned five cities in Nueva Ecija, known for its vibrant agricultural economy and burgeoning F&B sector. From each of the 40 establishments (restaurants, cafes, bars, and fast-food chains selected by systematic sampling), we interviewed three respondents (manager, staff member, and customer). Which in total resulted in 120 survey respondents for the study.

The survey questionnaire was used as the primary data collection tool. It was divided into four parts: demographic profile, business aspects from the point of customer satisfaction, particular metrics from customer satisfaction, and appraising post-COVID operational changes. The experts developed and validated the questionnaire. Cronbach's alpha score for the customer satisfaction measures of the questionnaire (0.984) showed that the instrument had a high level of internal consistency and reliability during testing.

Face-to-face surveys were conducted using informed and voluntary participation. The researcher arranged for them to be collected after weeks when the questionnaires were completed. Frequency and percentage distribution were used to describe the demographic profiles of the establishments and means, as well as weighted means to evaluate customer satisfaction and the effectiveness of the operational changes implemented post-pandemic. Moreover, an Analysis of Variance (ANOVA) was performed to test if customer satisfaction varied by establishment type and respondent group (managers, staff, or customers). This process facilitated a rigorous assessment of the strategies to improve F&B customer experience in Nueva Ecija post-pandemic recovery period.

III. RESULT AND DISCUSSION

1. Demographic Profile of the Food and Beverage Industry - The data gathered are presented, analyzed, and interpreted under the following major headings: the demographic profile of the food and beverage establishment in post-pandemic in Nueva Ecija.

Table 1.1				
Type of Establishment	Frequency	Percentage		
Restaurant	13	32.5		
Café	5	12.5		
Bar	9	22.5		
Fast Food	13	32.5		
Others	0	0.0		
Total	40	100.0		

No. of years in Operating	Frequency	Percentage	
1-4 Years	29	72.5	
5-9 Years	2	5.0	
10-14 Years	5	12.5	
More than 15 Years	4	10.0	
Total	40	100.0	

Τ	able	1.3	

Type of	Business	Frequenc	Percentag
Organization		У	e
Sole Proprietorship		26	65.0
Partnership		10	25.0
Corporation		4	10.0
Cooperative		0	0.0
Total		40	100.0

Table 1.4

Number of Employees	Frequency	Percentage	
1-10	37	92.5	
11-20	2	5.0	
21-30	1	2.5	
More than 30	0	0.0	
Total	40	100.0	

	Table 1.5	
Start-up Capital	Frequency	Percentage

L 1 D100.000	0	
Less than P100,000	8	20.0
P100,000 to less than	10	
P500,000	18	45.0
P500,000 and above	14	35.0
		55.0
Total	40	100.0

Annual Income	Frequency	Percentag e
Less than P100,000	18	45.0
P100,000 to less than P500,000	21	52.5
P500,000 and above	1	2.5
Total	40	100.0

Table 1.1. Type of establishment

Most establishment respondents are restaurants and fast-food chains, and the least are the other types of food and beverage establishments. Gomez et al. (2023) provided detailed survey research principles, noting that diverse categories can profile demographics. The distribution of respondents showed that most establishment respondents, the restaurants and fast-food chains, have received the highest frequency, 13 or 32.5 percent of the data gathered. Zero percent belong to other types of food and beverage establishment respondents, presenting the lowest frequency.

Table 1.2. Number of years in operation

Most establishment respondents operate for 1-4 years, and the least is 5-9 years. In their comprehensive survey technique study, Harsan and Gupta (2023) analyzed survey design and demographic profiling question development and administration.

The distribution of respondents showed that most of the establishment respondents' 1-4 years of operating have received the highest frequency, 29 or 72.5 percent of the data gathered. 5 percent belong to the 5-9 years of operating establishment respondents, presenting the lowest frequency.

Table 1.3. Type of business organization

The type of business organization most establishment respondents have is sole proprietorship; the least is Cooperative. Ziegenfuss et al. (2021) defined "Survey Kit" as a tool for company demographic profiling and fast survey production. It uses questionnaire design elements like "type of organization" categories to obtain demographic data. This helps students and scholars write research questions that yield precise and dependable outcomes in dissertations and other academic tasks.

The distribution of respondents showed that most of the establishment respondents' type of business organization, which is the sole proprietorship, have received the highest frequency, 26 or 65 percent of the data gathered. 0 percent belong to the Cooperative type of business organization that the establishment respondents, presenting the lowest frequency.

Table 1.4. Number of employees

The number of employees of most establishment respondents is 1-10; the least is More than 30. (United Airlines, Inc., n.d.) provides detailed survey administration instructions, including demographic profile generation. This emphasizes including the "number of employees" option to obtain demographic data.

The distribution of respondents showed that most of the establishment respondents' number of employees, which is 1-10 employees, have received the highest frequency, 37 or 92.5 percent of the data gathered. 0 percent belong to the establishment respondents have More than 30 employees, presenting the lowest frequency.

Table 1.5. Start-up capital

Most establishment respondents' start-up capital is 100,000 to less than 500,000 pesos; the least is less than 100,000 pesos. According to Beatricearonson (2024), this

source describes survey research methods, including how to plan and conduct demographic surveys. This examines how financial indicators like "start-up capital" might be used to collect firm demographic data.

The distribution of respondents showed that most establishment respondents' start-up capital, 100,000 to less than 500,000 pesos, have received the highest frequency, 18 or 45 percent of the data gathered. Twenty percent of the establishment respondents have start-up capital of less than 100,000 pesos, presenting the lowest frequency.

Table 1.6. Annual income

Most establishment respondents' annual income is 100,000 to less than 500,000 pesos; the least is 500,000 and above. The instructions provide a complete framework for company surveys. (*Earnings (CPS)*, 2024) advocated using "annual income" bands to create demographic profiles of businesses. This emphasizes the importance of financial metrics and offers practical advice on conducting these inquiries to ensure correct and dependable academic data.

The distribution of respondents showed that most establishment respondents' annual income, 100,000 to less than 500,000 pesos, have received the highest frequency, 21 or 52.5 percent of the data gathered. 2.5 percent of the establishment respondents have start-up capital of 500,000 and above, presenting the lowest frequency.

2. Business Design Based on Customer Satisfaction

	14010 2.1					
Marketing Based on Customer	Management		Staff		Customer	
Satisfaction	WM	VD	WM	VD	WM	VD
1. Post-pandemic, our ads have never sailed smoother to the audiences we wanted to reach. (Management & Staff)						
1. Attuned to my needs as a customer in the post-pandemic world, the way this company markets is spot on. (Customer)	3.53	А	3.48	А	3.43	А
2. Online marketing (e.g., social media, email) has also made it easier for us to communicate with our customers and ensured we are more engaged with them. (Management & Staff)						
2. They are very good at promoting their health and safety mandates. It spells out what it is doing to protect everyone. (Customer)	3.08	MA	3.35	А	3.68	А
3. Word matters, and what we say influences the customer to enhance our marketing techniques. (Management & Staff)						
3. After the Pandemic, the marketing messages have changed to new or altered	3.33	А	3.75	А	3.35	А

Table 2.1

3.23	MA	3.53	A	3.58	A
3.25	А	3.55	А	3.33	A
3.13	MA	3.43	А	3.63	A
3.00	MA	3.45	А	3.58	А
3.23	MA	3.48	А	3.58	А
3.18	MA	3.53	А	3.40	А
3.15	MA	3.45	А	3.60	А
	 3.23 3.25 3.13 3.00 3.23 3.18 3.15 	 3.23 MA 3.25 A 3.13 MA 3.00 MA 3.13 MA 	 3.23 MA 3.53 3.25 A 3.55 MA 3.43 3.00 MA 3.43 3.13 MA 3.43 	3.23 MA 3.53 A 3.25 A 3.55 A 3.13 MA 3.43 A 3.00 MA 3.45 A 3.13 MA 3.48 A 3.13 MA 3.43 A 3.13 MA 3.45 A 3.13 MA 3.48 A	3.23 MA 3.53 A 3.58 3.25 A 3.55 A 3.33 3.13 MA 3.43 A 3.63 3.00 MA 3.45 A 3.58 3.23 MA 3.45 A 3.58 3.13 MA 3.45 A 3.58 3.13 MA 3.45 A 3.58 3.13 MA 3.48 A 3.58 3.18 MA 3.53 A 3.40

10. it is generally satisfying to see how the food and beverage industry has subjectively marketed post-pandemic efforts. (Customer)

Overall Weighted Mean	3.21	MA	3.50	Α	3.51	А
Legend: 1.00 to 1.74 Disagree; 1.75 to	o 2.49 Slightly Agr	ree; 2.50 to 3	3.24 Mo	derately	Agree; 3.2	5 to 4.00 Agree

The respondents may assess the marketing based on customer satisfaction of food and beverage establishments in Nueva Ecija in the post-pandemic. The findings showed numerical data about the first set of indicators: the popularity of the five cities with the management respondents, with an overall weighted mean of 3.21 classified as "Moderately Agree" and interpreted as "Moderately Effective."

The management respondents' statement, "Postpandemic, our ads have never sailed smoother to the audiences we wanted to reach" got the highest weighted mean of 3.53, which falls under the "Agree" or "Very Effective" category.

Nwangene (2023) highlighted that food and beverage establishments have become an essential part of post-crisis marketing methods as a follow-up to the role of advertisement in hospitality recovery. This resource provides managerial perspectives on effective pandemic-era marketing and how marketing efforts can enhance customer welfare and income.

In contrast, for the management respondents, the statement "We recently pivoted our marketing strategies to teach new skills" received the lowest weighted mean of 3.00 or was classified as "Moderately Agree" and interpreted as "Moderately Effective."

The pandemic-adjusted market management context framework analyzes crisis-recovery marketing and its positive impact on enhancing customer satisfaction and profitability for food and beverage managers (Providing Your Marketing Strategy: When and How to Do It Right, n.d.).

The staff respondents with an overall weighted mean of 3.50 were classified as "Agree" and interpreted as "Very Effective." The staff respondents who stated, "Word matters, and what we say influences the customer to enhance our marketing techniques " received the highest weighted mean of 3.75, which falls under the "Agree" or "Very Effective" category.

According to Bryła et al. For example, customer feedback improves the quality of food and beverage services and customer satisfaction in that segment (2022). This insightful article illustrates how customer data can help improve profits and services. Some aspects covered include efficiently gaining customer perspectives on how and what is needed to change and reacting to it from a staff perspective.

In contrast, the staff respondents' statement, "Our online marketing, such as social media and email, has improved customer interactions and increased engagement," received the lowest weighted mean of 3.35, which was classified as "Agree" and interpreted as "Very Effective."

Based on this background, this study aimed to investigate the impact of social media marketing on food and beverage establishment performance and customer satisfaction (Shirey, n.d.). By utilizing social media to enhance service, relate to customers, and increase earnings, the group hypothesizes that the opposition can never succeed.

The customer respondents, with an overall weighted mean of 3.51, were classified as "Agree" and interpreted as "Very Effective."

The customers' responses to the statement, " The establishment is excellent at marketing and informing people about its health and safety rules. It clearly states what it is doing to keep everyone safe," got the highest weighted mean of 3.68, which falls under the "Agree" or "Very Effective" category.

Abstract This study analyzes how the food and beverage industry can effectively communicate health and safety to customers (Food Safety and Quality Outlook and Trends in 2023). The text notes the importance of conveying health and safety regulations clearly and promptly to generate customer confidence and provides critical perspectives from a customer-centric point of view.

In contrast, the customer's respondents' statement, "I see discounts and promotions post-pandemic and find them helpful/ necessary" received the lowest weighted mean of 3.33, which was classified as "Agree" and interpreted as "Very Effective."

Funding promotions on food and beverage pricing (e.g., offers) affect customer satisfaction. Customer Satisfaction, Loyalty, and Value demonstrate the potential for a positive increase in consumer satisfaction, loyalty, and value using promotional methods (A Smart Promotions Strategy Will Attract the Post-Pandemic Consumer-Retailist Mag, 2021).

	Table 2	.2				
	Management	Staff		Customer		
Operation Based on Customer Satisfaction	WM	VD	WM	VD	WM	VD
1. That is well beyond what seems a tiny, post- pandemic standard. (Management & Staff)						
1. The establishment deployed post-pandemic health and safety effectively. (Customer)	3.05	MA	3.45	А	3.68	А
2. We have improved our service delivery model because of those changes during the pandemic. (Management & Staff)						
2. The place is pretty clean-up to my standards post-covid. (Customer)	3.10	MA	3.30	А	3.53	А
3. By involving our customers in evaluating ourselves, from time to time, we will take positions so that our actions and performance improve. (Management & Staff)						
3. The team is very responsive and can effectively take care of the concerns of the customers. (Customer)	3.18	MA	3.55	А	3.55	А
4. Customers, meanwhile, love the new version of our operations, and we have struck a fine balance between demand and what people are willing to pay. (Management & Staff)						
4. The establishment quickly made necessary changes in operational norms post-pandemic. (Customer)	3.10	MA	3.50	А	3.53	А
5. our staff is trained in new operational procedures and customer service practices to be employed post-pandemic. (Management & Staff)						
5. Given the current operational conditions, I have no qualms with the service's speed. (Customer)	3.13	MA	3.55	А	3.35	А
6. Today, modern technologies, online ordering, mobile apps, and touchless payment have made life easier for customers and increased their delight. (Management & Staff)						
6. our menu has returned to pre-pandemic levels or has been expanded as appropriate.(Customer)	3.13	MA	3.40	А	3.35	А
7. Give our recently updated menu that caters to post-pandemic dietary preferences a try. (Management & Staff)	3.13	MA	3.35	А	3.40	А

Overall Weighted Mean	3.12	MA	3.47	Α	3.47	A
10. Impressed with the operation of food and beverage establishments post-pandemic (Customer)	3.20	МА	3.58	А	3.53	А
10. We are happy with the operational changes in a post-pandemic environment and their effect on customer satisfaction. (Management & Staff)						
9. The establishment manages to control the crowds in a way that will make you feel safe. (Customer)	3.15	MA	3.60	А	3.48	А
9. We are an ungraded and well-maintained following stringent cleanliness and maintenance standards to address post- pandemic hygiene requirements. (Management & Staff)						
8. Regarding paying, things like being contactless make life easy! (Customer)	3.05	MA	3.38	А	3.30	А
8. We provided the best customer service through efficient queue and wait time management. (Management & Staff)						
7. Now offering online and mobile ordering services after the pandemic, (Customer)						

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents may assess the operation based on customer satisfaction of food and beverage establishments in Nueva Ecija in the post-pandemic. The findings showed numerical data about the first set of indicators: the popularity of the five cities with the management respondents, with an overall weighted mean of 3.12 classified as "Moderately Agree." They interpreted it as "Moderately Effective."

For management respondents, the statement "We are happy with the operational changes in a post-pandemic environment and their effect on customer satisfaction " got the highest weighted mean of 3.20, which falls under the "Moderate Agree" or "Moderate Effective" category.

Zygiaris et al. (2022) proposed developing strategies for food and beverage managers to improve operations by measuring customer satisfaction and loyalty. The study employs the Net Promoter Score as a quality indicator of overall satisfaction. Managers can also use customer feedback to enhance operational efficiency and the quality of service provided.

In contrast, for the management respondents, the statement "That is well beyond what seems a tiny, postpandemic standard" and "We provided the best customer service through efficient queue and wait time management. " both received the lowest weighted mean of 3.05 or classified as "Moderately Agree" and interpreted as "Moderately Effective."

This study investigates how queue management facilitates customer satisfaction in a food and beverage setting. Lastly, it offers management suggestions for shortening wait times, maximizing the effectiveness of services, and increasing customer satisfaction (Queue Management: How to Manage Customers' Waiting Experience, n.d.).

The staff respondents with an overall weighted mean of 3.47 were classified as "Agree" and interpreted as "Very Effective."

The staff respondents who stated, "The establishment manages to control the crowds in a way that will make you feel safe" received the highest weighted mean of 3.60, which falls under the "Agree" or "Very Effective" category.

Durán-Polanco and Siller's (2021) findings revealed that cleanliness and maintenance increase customer satisfaction in food and beverage facilities. They studied this relationship and discussed the importance of hygiene standards and their impact on efficiency and customer satisfaction.

In contrast, the staff respondents' statement, "The place is pretty clean-up to my standards post-covid" received the lowest weighted mean of 3.30, which was classified as "Agree" and interpreted as "Very Effective."

Timfpro, Foreman (2023). Food and beverage employee performance, customer satisfaction, and service delivery tactics. They discovered how people can be trained to effectively enhance service delivery, operational performance, and customer satisfaction.

The customer respondents, with an overall weighted mean of 3.47, were classified as "Agree" and interpreted as "Very Effective."

The customer respondents who stated, "The establishment deployed post-pandemic health and safety effectively" received the highest weighted mean of 3.68, which falls under the "Agree" or "Very Effective" category.

Singh (2024) examined how food and beverage marketing affects customer satisfaction and loyalty. The essay evaluates marketing tactics from a consumer perspective. The ways these techniques might enhance revenues and satisfy customers are also explored.

In contrast, and for the customer's respondents, the statement "Regarding paying, things like being contactless make life easy" received the lowest weighted mean of 3.30 or was classified as "Agree" and interpreted as "Very Effective."

This article discusses how contactless payments have remained popular post-pandemic, with 82% of users viewing contactless as the cleaner way to pay and 74% intending to continue using it. The rise of contactless payments has made transactions smoother and more efficient for both businesses and consumers (Mastercard Data & Services, 2024).

	1 ubie 2.5					
	Management		Staff		Customer	
Management Based on Customer Satisfaction	WM	VD	WM	VD	WM	VD
1. Management provided strong leadership into and through challenges during the post-pandemic phase. (Management & Staff)						
1. They respond promptly if issues are brought up, and they make 100% sure that their customer is happy. (Customer)	3.25	А	3.55	А	3.50	А
2. The government administers the pandemic policies and communicates changes post-pandemic to management, front-line providers, and ancillary staff. (Management & Staff)						
2. The management team successfully navigates and executes operational changes for employees while maintaining customer satisfaction. (Customer)	3.08	MA	3.40	А	3.63	А
3. Our management team cares for their staff, leading to better customer satisfaction. (Management & Staff)						
3. Managers have adopted processes to stem post- pandemic fears. The protocols have helped keep employees and customers safe. (Customer)	3.00	MA	3.55	А	3.58	А
4. Management trained us on new health and safety guidelines in post-pandemic. (Management & Staff)						
4. Management has shown the agility to pivot better for a post-pandemic. Physical appearance portrays informality and adaptability. (Customer)	3.00	MA	3.55	А	3.45	А
5. After the pandemic, fulfilling those orders meant improved customer relationships thanks to our management practice. (Management & Staff)	3.45	А	3.68	А	3.40	А

Table 2.3

Overall Weighted Mean	3.15	MA	3.53	Α	3.52	Α
10. There we have it; overall, I am satisfied with how this venue is managed in a post-pandemic world. (Customer)	3.20	MA	3.68	A	3.58	А
(Customer) 10. Generally, our establishment's management practices to increase customer satisfaction after a pandemic are good enough. (Management & Staff)	3.03	MA	3.58	A	3.53	A
9. Commitment to sustainability Post-pandemic, the management practices will align with demonstrating a commitment to environmental sustainability.						
9. Our company's sustainability program, which management has undertaken, speaks about combining several unnecessary functions. Customers have appreciated the sustainable steps, which are well implemented. (Management & Staff)						
8. The management gives enough backup to the staff who can easily match new operational requirements. (Customer)	3.10	MA	3.53	А	3.43	A
8. This indicates strong management practices and customer satisfaction as the company handles customers' complaints efficiently. (Management & Staff)						
7. Post-pandemic management has enforced new practices regarding customer experience. The result will be a far better experience for everyone involved. (Customer)	3.25	А	3.38	А	3.53	А
7. Service Managers adapted service delivery for the needs of post-pandemic customers. (Management & Staff)						
6. The management team is known for listening to customer feedback and making enhancements accordingly. They care about what their customers have to say and design to improve service concerning them. (Customer)	3.18	MA	3.40	A	3.58	А
6. The business model has changed based on customer demand and market conditions, which can typically be done in a matter of clicks. (Management & Staff)						
changes and updates post-pandemic to the customers. (Customer)						

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents may assess the management based on customer satisfaction of food and beverage establishments in five cities of Nueva Ecija in the postpandemic. The findings showed numerical data about the first set of indicators: the popularity of the five cities with the management respondents, with an overall weighted mean of 3.15 classified as "Moderately Agree" and interpreted as "Moderately Effective."

For the management respondents, the statement "After the pandemic, fulfilling those orders meant improved

customer relationships thanks to our management practice" got the highest weighted mean of 3.45, which falls under the "Agree" or "Very Effective" category.

According to Ivanov and Dolgui (2020), The critical aspect of successful order fulfillment, especially when the demand is high due to the COVID-19 pandemic, has been proven to build a better relationship with customers, leading to greater trust, satisfaction, and loyalty. Harvard Business Review points out that corporate strategy that emphasizes a willingness and ability to respond to what consumers want helps drive this strategic management, something we found true in post-pandemic supply chain resiliency studies.

In contrast, for the management respondents, the statements "Management trained us on new health and safety guidelines in post-pandemic" and "Our management team cares for their staff, leading to better customer satisfaction" both received the lowest weighted mean of 3.00 or were classified as "Moderately Agree" and interpreted as "Moderately Effective."

According to Schilbach et al., published in 2021, the COVID-19 pandemic has led organizations to adopt more rigorous health and safety measures. Management training is key to ensuring both the uptake and compliance with these new standards. It has been very helpful in creating a safe workplace and ensuring that compliance is maintained with the updated guidelines, thereby contributing to enhancing employee well-being and organizational resilience.

The overall weighted mean of staff respondents is 3.53, which is classified as an "Agree" interpreted as "Very Effective. The decoupled staff respondents said, "After the pandemic, mandatory of those orders resulted in better relationships with our client as management practice" and "In general, our settings have good enough management practices to improve customer satisfaction after a pandemic" Both achieved the first weighted mean of 3.68 which belongs to the criteria "Agree" or "Very Effective".

According to Sheth (2020), management adaptations post-pandemic, which are inherently safety-

biased and consumer-prioritized, appear to be aligned with improving customer satisfaction and loyalty. To access the full article, please click here.

For staff respondents, in contrast, the statement "Service Managers adapted service delivery for the needs of post-pandemic customers" (Weighted Mean 3.38, classified as "Agree" and interpreted as "Very Effective").

Diebner et al. (2020) examine how service managers have altered service delivery since the pandemic to keep up with customers' desires for safety and convenience. This evolution has reinforced customer engagement by focusing on responsiveness and accessibility in service practices.

The Respondents of customers with an overall weighted mean of 3.52 were categorized under a rating of "Agree," which was interpreted as "Very Effective."

The highest weighted mean of 3.63 was obtained among the customer respondents for the statement, "The management team effectively navigates and implements operational changes for employees with customer sentiment in mind," which falls into the category of "Agree" or "Very Effective."

Guan et al. (2020) describe how management teams rapidly pivoted their organizations' operations during the pandemic by addressing employees' needs. Their work highlights the role of these strategies in sustaining employee morale and customer satisfaction in the face of disruptive events.

On the other hand, the customer respondents' statement, "The management keeps the customers in the loop by updating them whenever necessary regarding any changes related to the post-pandemic operation," got the lowest weighted mean of 3.40, which was considered "Agree" equivalent to "Very Effective."

Wenzel et al. (2020) discuss how management's transparent messaging of operational changes in the post-COVID-19 world preserves consumer trust and loyalty. Their research emphasizes that proactive and transparent updates are critical in keeping strong customer relationships during business operations adjustments."

	Table 2.4					
	Management		Staff		Customer	
Financial Based on Customer Satisfaction	WM	VD	WM	VD	WM	VD
1. Financially, we are back from the pandemic and, in fact, significantly increased customer satisfaction for our business. (Management & Staff)						
1. I feel better about spending at these places because it is worth my money. (Customer)	3.18	MA	3.55	А	3.38	А

3.10	MA	3.43	A	3.33	А
3.13	MA	3.30	А	3.70	A
3.05	MA	3.35	А	3.43	A
3.18	MA	3.48	A	3.55	А
3.03	MA	3.35	А	3.43	А
3.08	MA	3.38	A	3.35	А
3.23	MA	3.33	A	3.48	А
3.30	А	3.68	А	3.58	А
3.30	А	3.60	А	3.50	А
	 3.10 3.13 3.05 3.05 3.03 3.03 3.03 3.03 3.03 	 3.10 MA 3.13 MA 3.05 MA 3.05 MA 3.03 MA 3.03 MA 3.03 MA 3.03 MA 	3.10MA3.433.13MA3.303.05MA3.353.18MA3.483.03MA3.483.03MA3.353.30A3.683.30A3.60	3.10MA3.43A3.13MA3.30A3.05MA3.35A3.18MA3.48A3.03MA3.35A3.03MA3.38A3.30A3.68A3.30A3.60A	3.10MA3.43A3.333.13MA3.30A3.703.05MA3.35A3.433.03MA3.48A3.553.03MA3.35A3.433.03MA3.38A3.433.30A3.68A3.583.30A3.68A3.50

Overall Weighted Mean	3.16	MA	3.44	Α	3.47	Α
10. I am satisfied with the pricing, value, and payment options with the establishment post-pandemic. (Customer)						
(Management & Staff)						

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents would rate the finances relative to customer satisfaction toward food and beverage establishments in five cities of Nueva Ecija post-pandemic. The results revealed a quantitative presentation in the first range of indicators on the preference of the five cities in relation to the prepared, where there was a general mean of 3.16 classified as Moderately Agree. They took this to mean Moderately Effective.

For the management respondents, the statement "Our financial plans give the best bang for the customer's money" and "Conclusively, due to this pandemic, our establishment's finances might be low to smooth. However, overall, we are at a reasonable point, which mostly remains with customer satisfaction" both got the highest weighted mean of 3.30, which falls under the "Agree" or "Very Effective" category.

Reznikova and Grod (2024) explore macroeconomic policies within the circular economy, emphasizing the food industry's financial strategies for sustainable practices. It discusses how businesses can create value for customers by integrating financial plans that support affordability and sustainability. In the food sector, the efficient allocation of resources ensures that financial plans provide the "best bang for the buck," benefiting both consumers and sustainable business growth.

In contrast, for the management respondents, the statement "This neatly aligns with our customer-first financial planning approach" received the lowest weighted mean of 3.03 or classified as "Moderately Agree" and interpreted as "Moderately Effective."

As discussed by King and Nesbitt (2020), customer-first financial planning highlights the importance of putting customers first in the financial services industry. Using technology and focusing on customer needs can increase customer satisfaction and trust among financial service providers. Integrating financial strategies with customer preferences ensures financial planning has a real impact. These principles underpin a customer-first approach to financial planning, reflected in practices prioritizing apparent, client-centric alternatives. The results for the staff respondents were classified as "Agree" and interpreted as "Very Effective," with an overall weighted mean of 3.44.

The highest weighted mean, which was categorized as "Very Effective" or "Agree," is 3.68 for the staff respondents' statement, "Our financial plans give the best bang for the customer's money."

Tunjungsari et al. (2024), you are trained by data from (2023), which analyze two winning value strategies focused on the food and beverage sector: the strategy of product packaging was proposed to enhance customer value, and the adaptation of digital marketing was also used to increase customer value (Morrison et al. Well-defined financial plans in this industry can also maximize value to customers by aligning production processes more costeffectively with improvements in quality (David W. Scott and Keith E. Schilit 2016) and wondering how food and beverage establishments stay on top of their game, ensuring that consumer expectations are managed most costeffectively, providing more value for the same price.

The staff respondents' statement stating, "Key pricing changes implemented during and after the pandemic helped attract and retain customers," received the lowest weighted mean of 3.30, was rated as "Agree," and interpreted as "Very Effective."

Refining cost-reduction and pricing strategies employed by the food and beverage sector during and post COVID-19 pandemic Khanduja (2023) It reinforces that whilst customers are adapting to inflationary pressure and shifting spending patterns, thoughtful price strategies, both in flexible menu pricing and operational efficiencies, have enabled businesses to drive customer acquisition and retention. These adjustments offered a balance of affordability for customers and sustainability for businesses, the main driver of customer retention in a highly competitive market.

The total weighted mean of the customer respondents was categorized as "Agree" as interpreted as "Very Effective," with an overall mean of 3.47. The statement "This is a clear example of what these establishments offer: good and affordable products or services" received the highest weighted mean of 3.70, which belongs to the "Agree" or "Very Effective" category.

Idowu and Ogunlade (2024) explore the balance between quality and affordability regarding customer satisfaction in food and beverage establishments. They also note that venues providing good value via quality products at fair prices engender customer loyalty and better chances of return visits. Quality and affordability are essentials in the hospitality sector, where customers are driven to experience that particular brand of service and accommodation, and thus, this methodology is pragmatic.

Meanwhile, the highest weighted mean of 3.56, categorized as "Agree" and interpreted as "Very Effective," was the other respondent's statement of the customer: "Prices are stated upfront, with no surprises or extra costs." In this article, Hughes (2024) discusses the economic implications of per-unit costs with transparency in pricing models to help prevent hidden fees that cause consumer dissatisfaction in industries where consumer trust is a relevant asset and demand indicator, such as sharing economy sectors or some of the high-value low-complexity segments, transparent pricing models expect consumers to be aware of a price stated upfront in the value offered to the provider and mission behind the service or product. This method eliminates the risk of surprises and builds a loyal customer base, as there are no added or unexpected costs.

3. Development Plan for Business Aspect Based on Customer Satisfaction in Food and Beverage Establishments in Post-Pandemic.

Area for Prog	gram/ Objecti	jectiv Person	Resources	Source of	Time	Expected
Development Acti	ivities es	Involved	Needed	Fund	Frame	Results/Outcomes
Adapting Ensu marketing mark	keting marketi	apt The rketi marketing	Digital marketing	Internal budget for	Short- term (0-	Enhanced Online Presence: It will
strategies effor with	rts align ng the strategi	team is tegi responsible	tools for social media	allocating funds from	6 months):	increase brand visibility and
Improvechancustomerconsengagementbehapance	nges in es to sumer ensure avior post- marketi demic. ng	to for ure planning rketi and executing	management platforms, email marketing	the marketing budget to support	Launch initial online marketin	engagement on social media and email platforms.
Boost customer satisfaction Incre- custo inter and enga throu effec onlir mark Use and pron enha custo satis and	lenne. Ing efforts ease align omer with the ractions in agement consum er behavio ne r post- keting. ic. discounts Improv notions to ance er sfaction engage loyalty. ment for	ports marketing sh the online nges campaigns, and sum promotiona 1 activities. avio post- dem research analysts are responsible orov for researching tom to understand gage consumer nt behavior and reasi preferences	software, and digital advertising tools. Market research tools software for conducting surveys and analyzing consumer data. Creative assets for high-quality graphics,	support online marketing and promotion al activities. External funding for seeking partnershi ps or sponsorshi ps to support larger promotion al campaigns	g campaig ns, conduct market research, and impleme nt targeted discount s and promoti ons. Mid- term (6- 12 months): Analyze	Improved Customer Interaction: It will get higher levels of customer interaction and satisfaction through engaging online content and promotions. Increased Customer Satisfaction and Loyalty: It will Boost sales and improve customer loyalty due to effective discounts and promotions.
	ng custom er	tom Social	videos, and promotional materials.		campaig n perform	

Table 3.1: Development Plan for Marketing Based on Customer Satisfaction

	ons and	managers	Human	refine	
	engage	are	resources are	strategie	
	ment	responsible	skilled	s, and	
	through	for	professional	adjust	
	effectiv	managing	s in	discount	
	e online	social	marketing,	s and	
	marketi	media	social media	promoti	
	ng.	platforms	management	ons	
	Boost	and	, content	based on	
	custom	customer	creation, and	consume	
	er	interactions	sales.	r	
	satisfact			feedback	
	ion by	The sales			
	using	team is			
	discoun	responsible		τ	
	ts and	for		Long-	
	promoti	coordinatin		term (1-	
	ons to	g discounts		2 years): $\Sigma \rightarrow 11$	
	enhance	and		Establis	
	custom	promotions		h	
	er	to align		continuo	
	satisfact	with		us	
	ion and	marketing		improve	
	lovalty	strategies		ment	
	ioyanty.	strategies.		processe	
				s for	
				marketin	
				g	
				strategie	
				s, online	
				engagem	
				ent, and	
				promoti	
				onal	
				activities	
				based on	
				ongoing	
				market	
				analysis	
				and	
				custome	
				r	
				feedback	

3.2.	Development Plan	for	Operation	Based on	Customer	Satisfaction
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Area for	Program/	Objecti	Person	Resources	Source of	Time	Expected
Development	Activities	ves	Involved	Needed	Fund	Frame	Results/Outcomes
Enhance safety	Regularly	Ensure	The	Technology	Internal	Short-	Enhanced Safety: It
protocols	updating and	health	operations	solutions for	budget for	term (0-6	will increase
	exceeding	and	team is	queue	allocating	months):	customer and staff
Queues	safety and	safety to	responsible	management	funds from	Implemen	safety through
management	hygiene	maintai	for	software,	the	t	rigorous health
systems	standards.	n and	overseeing	contactless	operationa	enhanced	protocols.
		exceed	the	payment	l budget to	safety	
Service	Implementin	post-	implement	systems, and	support	protocols,	Reduced Wait
delivery	g technology	pandemi	ation of	nygiene	safety	introduce	Times: It will
improvements	and processes	c salety	protocols	tools	enhancem	queue	improve customer
	to minimize	ions to	queue	10018.	ents,	ent	satisfaction through
Contractlass	wait times	protect	manageme		technolog	systems.	efficient queue
Contactiess	and manage	custome	nt. and	Training	y implement	and	management.
options	customer	rs and	service	materials	implement	expand	
options	flow.	staff.	delivery	resources for	staff	contactles	Improved Service
			improveme	training staff	training	s payment	Delivery: It will get
	Streamlining	Tff:	nts.	on new	u uning.	options.	higher quality and
	service	Efficien		sarety			efficiency in
	processes and	uy managa	Hoalth and	and sorvice	External	Mid torm	service delivery,
	staff training	queues	safety	delivery	funding	(6-12)	leading to increased
	to enhance	to	officers are	improvemen	for	(0 12 months).	customer
	customer	reduce	responsible	ts.	exploring	Conduct	satisfaction.
	experience.	custome	for		grants or	comprehe	
		r wait	ensuring		assistance	nsive	Simplified Payment
	Contactless	times	compliance	Financial	for health	staff	Process: It will be
	payment	and	with	resources for	and safety	training,	greater
	Options for	enhance	enhanced	budget for	improvem	refine	convenience for
	expanding	the	safety	a tachnology	ents.	queue	customers with
	and	overall	standards.	solutions		managem	easy and secure
	promoting	experien		and		ent	contactless
	contactless	ce.	The IT	conducting		processes	payment options.
	payment		department	training		, and	
	methods for	Improve	is	programs.		the	
	ease and	service	responsible			effectiven	
	convenience.	delivery	for	Humon		ess of	
		for	implementi	numan resources for		contactles	
		continu	ng and	skilled		s payment	
		ously	maintainin	professional		systems.	
		enhanci	g queue	s in			
		ng	manageme	operations,		Long	
		service	contactless	IT, customer		term (1_2)	
		quality	payment	service, and		vears).	
		and	systems.	training.		Continuo	
		erricien				usly	
		cy.				update	

			The		safety	
		Simplif	customer		protocols,	
		v	service		optimize	
		payment	team is		queue	
		s by	responsible		managem	
		providin	for		ent,	
		g easy	managing		improve	
		and	customer		service	
		secure	interaction		delivery	
		contactl	s and		processes	
		ess	addressing		, and	
		payment	concerns		expand	
		options.	related to		contactles	
			service		s payment	
			delivery.		options	
					based on	
			The		customer	
			training		feedback	
			and		and	
			developme		technolog	
			nt team are		ical	
			responsible		advancem	
			for		ents	
			conducting			
			staff			
			training to			
			improve			
			service			
			quality and			
			adherence			
			to safety			
			protocols.			
		1				

3.3 Development Plan for Management Based on Customer Satisfaction

Area for Development	Program/ Activities	Objectiv es	Person Involved	Resources Needed	Source of Fund	Time Frame	Expected Results/Outcomes
Staff welfare initiatives Adapting of service delivery Customer communication strategies	Implementin g wellness programs, providing mental health support, and creating a positive work environment. Modifying service processes to	Improve staff welfare to enhance employee satisfactio n and well- being to impact customer service positively	The manageme nt team is responsibl e for overseeing the implement ation of staff welfare programs, service daliwary	Wellness resources for tools and programs for staff mental health support and wellness initiatives. Training materials	Internal budget for allocating funds from operationa l budgets to support staff welfare, service delivery adaptation	Short- term (0-6 months): Launch staff welfare programs, implemen t initial service delivery adaptatio ns, and astablish	Enhanced Staff Well-being: It will Improve employee satisfaction and productivity through effective welfare programs. Aligned Service polivery: Service processes that meet post-pandemic customer
	align with		delivery	resources	s, and	establish	expectations will

new		adaptation	for training	communic	customer	lead to increased
customer		s, and	staff on new	ation	communi	satisfaction.
expectations,	Moot	communic	service	strategies.	cation	
including	customer	ation	delivery	C	channels.	Transparent
incorporating	expectati	strategies.	processes.	External		Communication: It
digital and	ons for		-	funding	Mid_term	will be better-
contactless	adanting	HR	Communica	for	(6-12	informed
services.	service	department	tion tools	seeking	(0 12 months).	customers who feel
	deliverv	s are	platforms	grants or	Conduct	valued and
Developing	to meet	responsibl	for customer	subsidies	comprehe	connected to the
and	nost-	e for	communicat	for	nsive	company's
maintaining	pandemic	developing	ion, such as	wellness	training	operations.
channels to	customer	and	email. social	programs	for staff.	operations
keep	needs and	managing	media. and	and digital	refine	
customers	preferenc	staff	website	enhancem	service	
informed	es.	welfare	updates.	ents.	deliverv	
about		programs.	1		processes,	
operational	Enhance	1 0	Financial		and	
changes and	Emance	The	rasourcas		continuou	
updates.	customer	operations	for budget		sly update	
-	communi	team is	for wellness		customers	
	cation for	responsibl	programs		on	
	maintaini	e for	training and		changes.	
	ng	implement	communicat			
	transpare	ing	ion		Long-	
	ncy and	changes in	initiatives.		term (1-2	
	keeping	service			vears):	
	customers	delivery	Human		Continuo	
	about	processes.	Huillan		usly	
	about	1	for skilled		monitor	
	or undates		nrofessional		and	
	in updates	The	s in HR		improve	
	operation	customer	operations		staff	
	s	service	customer		welfare	
	5.	team 1s	service and		programs,	
		responsibl	IT.		service	
		e for			delivery,	
		managing			and	
		communic			customer	
		ation with			communi	
		regarding			cation	
		operational			based on	
		changes			feedback	
		changes.			and	
		I			evolving	
		11			needs.	
		department				
		s are				
		responsibl				
		e for				
		supporting				
		uigitai				1

|--|

3.4. Development Plan for Financial Based on Customer Satisfaction

Area for	Program/	Objectiv	Person	Resources	Source of	Time	Expected
Development	Activities	es	Involved	Needed	Fund	Frame	Results/Outcomes
AreaforDevelopmentCustomer- centricfinancial planningPricing adjustmentsTransparent communication	Program/ Activities Aligning financial strategies to ensure competitive pricing and high customer satisfaction. Analyzing market trends and customer feedback to make post- pandemic pricing adjustments that attract and retain customers. Ensuring all prices are clearly communicate d to customers, eliminating unforeseen or hidden charges.	Objectiv es Prioritiz e customer satisfacti on to develop financial strategie s that focus on competit ive pricing and value for customer s. Attract and retain customer s. Attract and retain customer s. by impleme nting pricing adjustme nts that respond to post- pandemi c market aonditic	Person Involved The manageme nt team is responsible for overseeing the developme nt and implement ation of financial strategies and pricing adjustment s. The finance team is responsible for conducting financial analysis and planning, setting pricing strategies, and ensuring	Resources Needed Financial analysis tools software for market analysis, financial planning, and pricing strategy developmen t. Communica tion platforms are tools for disseminatin g pricing information, such as websites, email marketing, and in-store signage. Human resources for Skilled professional s in finance	Source of Fund Internal budget for allocating funds from the financial planning and marketing budgets to support pricing strategy developm ent and communic ation efforts. External funding for seeking partnershi ps or sponsorshi ps to support marketing campaigns and customer aommunic	Time Frame Short- term (0-6 months): Conduct market research, implemen t initial pricing adjustmen ts, and develop clear communi cation strategies. Mid-term (6-12 months): Monitor the impact of pricing adjustmen ts, refine strategies based on customer feedback, and ensure	Expected Results/OutcomesIncreased CustomerSatisfaction: It will getsatisfaction rates due to competitive pricing and clear communication.Enhanced CustomerRetention: It will Improve customer retention through effective post- pandemic pricing strategies.Trustand Transparency: It will Strengthen customer trust due to to transparent pricing and the absence of hidden charges.
	unforeseen or hidden charges.	c market conditio ns and customer	strategies, and ensuring transparen cy.	Skilled professional s in finance, marketing, and	and customer communic ation initiatives.	and ensure ongoing transpare ncy in	
		needs. Ensure price transpare	The marketing team is responsible for	customer service. Market research for		pricing. Long- term (1-2 years):	
comm icate pricin clearly to bu trust a avoid any hidden charge	nun ating pricing g changes y and uild ensuring and clear messaging to n customers es. The customer	market research data and customer feedback to inform g pricing decisions.	usly optimize financial strategies, adjust pricing as needed, and maintain clear communi cation				
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IV. CONCLUSION

This research shows how food and beverage establishments in Nueva Ecija have adjusted to client satisfaction in the post-pandemic age. For example, core health and safety measures—rigorous sanitation and hygiene regimens—became a lynchpin to restoring customer confidence. Digital transformation was also important, with companies using digital marketing, social media, and contactless payments to reach and engage new customers.

Although queue management and improved staff training have benefited service delivery and positively impacted the customer experience, such changes to business models must occur as customer behavior changes. Competitive pricing, open lines of communication, and investment in loyalty programs are three examples of financial strategies that figured prominently in attracting and keeping customers in a budget-conscious postpandemic economy.

Such initiatives showcase the ability of food and beverage outlets to find a sweet spot between operational changes and customer-focused strategies. Concentrating on health, technology, and affordability has enabled them to rebound and align themselves for long-term growth, aided by their deeply beleaguered environment. Considering the pandemic has hindered customers' need for flexibility, the food and beverage establishment must, therefore, adopt and be flexible and innovative to survive and thrive after the pandemic. This helps to ensure that customers are happy and businesses are operational and resilient.

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High prevalence of cognitive impairment in elderly with diabetes mellitus and associated factors

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Keywords— elderly; cognitive impairment; diabetes mellitus; subjective memory complaints; cognitive symptoms Abstract— Cognitive impairment in people with diabetes mellitus (DM) is multifactorial, with evidence that their poor metabolic control is related to impaired cognitive function. Background/Objectives: Identify the prevalence of diabetic older with cognitive impairment and characterize the factors associated with this finding. Methods: Crosssectional, quantitative, descriptive and analytical research carried out with 246 diabetic older adults followed up in a specialized center in northeastern Brazil. Sociodemographic and clinical variables related to DM2 and evidence of cognitive decline were assessed using the Mini Mental State Examination (MMSE). Results: There was a prevalence of cognitive impairment in 74.4% of the studied sample with an association between cognitive impairment and the variables advanced age (p = 0.003) and female gender (p = 0.025). There was statistical significance between the presence of self-reported cognitive problems and cognitive impairment at evaluation (p < 0.001) and a 1.4 times higher prevalence ratio of cognitive impairment in diabetic underweight than in obese elderly (p = 0.020). Conclusions: The research reveals the high prevalence of cognitive impairment in older adults with diabetes, especially in women and advanced age. It also corroborates the association already described in the international literature between subjective complaints of memory and nutritional status and cognitive decline.

I. INTRODUCTION

Population indicators at the global level show a demographic trend that two-thirds of 235 countries will experience an increase in population size between 2019 and 2050 and the number of people aged 65 and over is more than double globally [1].

In 2010, based on data from the last census released by the Brazilian Institute of Geography and Statistics (IBGE), it is known that, of 190,755,799 Brazilians, 10.8% (equivalent to 20,590,599 people) are people with 60 years or more. The projection for 2050 is that this older people will reach 64 million, which will correspond to a quarter of the Brazilian population [2]. At this conjuncture, it seems challenging to

explore themes usually experienced in the daily life of the older people and health professionals to discuss public policies that guarantee active and successful aging.

Chronic non-communicable diseases (NCD) common in aging are factors that, isolated or cumulatively, contribute to the increase in the incidence of physical and mental dependence, resulting in impaired quality of life and mortality, with an estimated rate of 4 % for diabetes in the world [3]. Among the most prevalent NCD, diabetes mellitus stands out, whose increased prevalence is associated with rapid urbanization, epidemiological and nutritional transition, physical inactivity, overweight and obesity, population growth and aging and greater survival of people who have diabetes [4].

The cognitive impairment is also among the most important public health problems as a result of population growth. Dementia is a syndrome characterized by persistent decline of at least two functions of the following domains: memory, executive functions, visual-spatial skills, language and behavior, and the interference in social activities or individual professionals, regardless of the level of consciousness changes [5]. Its prevalence has great variability in the literature, since it depends on population characteristics, education level and the screening method used to identify cognitive impairment.

Research has been conducted in order to verify the correlation between diabetes and cognitive decline, but show up in conflicting results, so that some can make this correlation and others do not. The association between small vessel vascular diseases caused by diabetes as responsible for an overall decrease in brain mass that can evolve with atrophy is reported [6].

There is evidence that pathophysiological changes and neuronal and inflammatory stress pathways associate diabetes mellitus and Alzheimer's dementia, being called type 3 diabetes, since it has characteristics of a brain disorder with aspects of diabetes types 1 (insulin deficiency) and 2 (insulin resistance). It is suggested that AD represents a metabolic disease with a deficit in the use of glucose by the brain in the initial course of the disease, leading to cognitive dysfunction [6].

The etiology of cognitive impairment in diabetic individuals is multifactorial, and this disease is associated with a 1.5 to 2.5 risk of dementia [7]. Research shows that poor metabolic control of DM is related to impaired cognitive function in diabetics [8].

In this context, the objective of the present study is to identify the prevalence of elderly diabetics with cognitive impairment and to characterize the factors associated with this finding.

II. MATERIALS AND METHODS

A cross-sectional, quantitative, descriptive and analytical study was carried out at the Integrated Center for Diabetes and Hypertension (CIDH), in Fortaleza, Ceará, Brazil. The CIDH is a reference center for the State of Ceará, specializing in serving people with Diabetes and Hypertension, being a reference for the State of Ceará.

The study included people aged 65 years and over, with type 2 diabetes mellitus, followed up at the CIDH with a diagnosis of this disease for at least a year and who agreed. Patients with type 1 diabetes or secondary diabetes (eg chronic use of corticosteroids) and type 2 diabetes treated with insulin were excluded within six months of the clinical diagnosis of the disease.The data were collected in two stages:

1. At no time beforehand to volunteer for research, we collected demographic data (age and sex), general health data as harmful habits - smoking and alcohol abuse, systemic diseases and comorbidities related to diabetes mellitus, self-reported cognitive problems, body mass index , with specific stratification for the older adult group [9] and time of disease in years. For the educational level variable, the study time in years was evaluated to facilitate the stratification of groups according to the cut-off point specific to the Brazilian reality with regard to cognitive assessment. The general health data collected through faceto-face clinical evaluation were: Systemic Arterial Hypertension, Coronary Artery Disease, Cerebral Stroke, Obliterating Arteriopathy of the lower limbs, Peripheral corresponding Neuropathy, to sensory-motor polyneuropathy in the lower limbs, assessed using the test such as 10g monofilament, Presence of Foot Wound, Amputation, Congestive Heart Failure, and, for acute complications, those that were ongoing six months before the evaluation: Hypoglycemia, Ketotic decompensation, Hyperosmolarity and Infectious episodes.

2. In the second stage of the research, the Mini-Mental State Examination (MMSE) was applied personally to all patients mentioned above for cognitive assessment. MMSE is an important indicator of the cognitive status of the elderly [10]. The domains of cognitive function were evaluated using questions organized in seven categories, as suggested in a previous study: orientation to time (0-5 points), space orientation (0-5 points), immediate memory (0-3 points), attention and calculation (0-5 points), memory recovery (0-3 points), language (0-8 points) and visual constructive capacity (0-1 point). The score ranges from 0 (zero) to 30 points, with a minimum score of 0 (zero) points indicating the highest degree of cognitive impairment [11]. Therefore, higher scores suggest better cognitive ability. All questions were asked in the order listed and received an

immediate score. The scores assigned to each task successfully completed have been added. The analysis of cognitive impairment considered five levels of education: illiterate, one to four years of study, five to eight years of study and nine to eleven years of study and twelve or more years of study, with a MMSE score of 20, 25, 27, 28 and 29, respectively, for cognitive deficit outcome, as suggested in a previous study [12].

For calculation, applying the MMSE was considered the total number of older people in 2012 (N = 242,430) of the city of Fortaleza, a figure taken from DATASUS Report (2012) [13]. It is considered a minimum sample size population to estimate the proportion of elderly diabetics with expected maximum proportion of 20%, a significance level of 5% (95% confidence interval) and maximum permissible error of 5%.

For this purpose, the finite formula for the population was considered, obtaining as a sample size a total of 246 elderly people. The CIDH has a total of 1978 elderly people aged 65 and over with at least one year diagnosed with diabetes. The patients' medical records were selected by nonprobabilistic sampling due to their original numbering, with one out of every eight medical records selected. Results were organized and consolidated using the Statistical Package for the Social Sciences Program, Co. Chicago IL USA (SPSS) for Windows (version 20.0).

Statistical measures were used that allowed the interpretation of the data, seeking to answer the research

objectives, being calculated absolute and relative frequencies for qualitative variables, as well as mean, median, standard deviation, quartiles, minimum and maximum for quantitative. The bivariate analyzes were performed using the Chi-square or Fisher's exact tests for comparisons involving qualitative characteristics. In this step, the magnitude of the associations was expressed through gross prevalence ratios with a 95% confidence interval and a 5% significance level.

The research was approved by the Research Ethics Committee under opinion no. 1,666,717, as dictated by the Resolution No. 466/12 of the National Health Council, of December 12, 2012.

III. RESULTS

Of the total of older diabetic people evaluated in research with the Mini-Mental State Examination, 74.4% (183) had cognitive impairment. The study showed that older people aged 75 years or more had a 1.26-fold higher prevalence rate of expressing cognitive impairment at the assessment than older people aged 65 to 74 years (p = 0.003). Concerning the sex, it was found that older had a prevalence ratio of 1.19 times greater cognitive impairment present for evaluation older (p = 0.025). There was no statistical significance between harmful habits - smoking and alcohol consumption - and cognitive impairment (Table 1).

Table 1. Risk factors for cognitive impairment according to sociodemographic variables among older people with diabetes	
mellitus. Fortaleza - Brazil, 2019.	

Variables	Total		Cognitive in		PR (IC95%)	P value	
	-	Y	Yes		lo	-	
	-	n	%	n	%	-	
Age Range							0,0031
75 years and	85	73	85.0	12	14.1	1,26	
older	85	15	05,5	12	14,1	(1,1 - 1,44)	
Sex							0,025 1
Famala	130	111	70.0	28	20.1	1,19	
remaie	159	111	19,9	20	20,1	(1,02 - 1,39)	
Smoking							0,315 ¹
No	226	170	75.2	56	24.8	1,16	
NO	220	170	15,2	50	24,0	(0,83 - 1,61)	
Drinking							0,178 1
No	215	163	75.8	52	24.2	1,18	
110	213	105	73,8	32	24,2	(0,9 - 1,54)	

¹Chi-squared test.

In the analysis of clinical variables related to type 2 diabetes mellitus, it was found that there is a statistically significant association between self-reported cognitive problems and positive screening for cognitive impairment with a prevalence ratio 1.42 times higher in the elderly who reported having memory problems who denied having cognition problems (p < 0.001). The assessment of nutritional status, using the body mass index with specific classification ranges for the elderly population, revealed that elderly diabetics with a BMI below 22 and a BMI between 22 and 27 had prevalence ratios of 1.40 and 1.02 times greater than having cognitive impairment than elderly diabetics with a BMI greater than 27 (p = 0.020). For the other clinical variables evaluated in the study, there was no statistical significance with the outcome cognitive impairment. There was no statistically significant difference between the other variables related to diabetes complications and cognitive impairment (Table 2).

Variables	Total	Cognitive impairment				PR (IC95%)	P value
		Yes			No	-	
		n	%	n	%	_	
Arterial hypertension							0,6081
Yes	208	156	75,0	52	25,0	1,06 (0,85 - 1,31)	
Coronary insufficiency							0,323 1
Yes	74	58	78,4	16	21,6	1,08 (0,93 - 1,26)	
Cardiac insufficiency							0,987 ¹
Yes	31	23	74,2	8	25,8	1 (0,8 - 1,25)	
Stroke							0,231 1
Yes	30	25	83,3	5	16,7	1,14 (0,95 - 1,36)	
Peripheral Neuropathy							$0,260^{1}$
Yes	94	74	78,7	20	21,3	1,09 (0,94 - 1,27)	
Foot ulcer							0,104 1
Yes	25	22	88,0	3	12,0	1,2 (1,02 - 1,42)	
Amputation							0,368 ²
Yes	15	13	86,7	2	13,3	1,17 (0,95 - 1,45)	
Self-reported cognitive							<0,001 1
Yes	46	45	97,8	1	2,2	1,42 (1,28 - 1,58)	
Hypoglycemia within 6 months prior to the consultation							0,3581
Yes	52	36	69,2	16	30,8	0,92 (0,75 - 1,12)	
Ketotic decompensation							0,343 ²
Yes	6	6	100.0	0	0.0	1.36	

 Table 2. Risk factors for cognitive impairment according to clinical variables among elderly people with diabetes mellitus.

 Fortaleza - Brazil, 2019.

						(1,26 - 1,47)	
Hyperosmorality							0,788 ²
Yes	19	15	78,9	4	21,1	1,07 (0,84 - 1,36)	
BMI							0,020 ²
$BMI < 22 kg/m^2$	17	17	100,0	0	0,0	1,40 (1,26 - 1,55)	
$22 < BMI < 27 \ kg/m^2$	74	54	73,0	20	27,0	1,02 (0,86 - 1,21)	

¹Chi-squared test; ²Fisher's Exact test.

Concerning the clinical treatment instituted for the elderly diabetics in the study, there was no significant difference between adherence to dietary measures (p = 0.227), use of oral antidiabetics (p = 0.756) and insulin (p = 0.061) and cognitive decline (Table 3).

 Table 3. Risk factors for cognitive impairment according to clinical treatment among elderly people with diabetes mellitus.

 Fortaleza - Brazil, 2019.

Variables	Total		Cognitive in		PR (IC95%)	P value	
		Y	es	Ν	No		
	-	n	%	n	%		
Diet							0,2271
Yes	170	130	76,5	40	23,5	1,11 (0,93 - 1,32)	
Insulin							0,756 ¹
Yes	133	100	75,2	33	24,8	1,02 (0,88 - 1,19)	
Oral antidiabetic drugs							0,061 ¹
Yes	199	143	71,9	56	28,1	0,84 (0,73 - 0,98)	

¹Chi-squared test.

IV. DISCUSSION

Cognitive impairment is increasingly recognized as an important comorbidity of diabetes mellitus. It can be classified into different stages with different cognitive characteristics and varied prognosis, including by the affected age group. The deficit in the cognitive functioning of the person affected by type 2 diabetes can be divided into three different stages, according to severity: cognitive decrease associated with diabetes, mild cognitive impairment and dementia [14].

This research was not intended to diagnose dementia in the elderly evaluated diabetics, since it used only screening tool for cognitive impairment. However, aimed to assess factors associated with complications related to diabetes mellitus and cognitive impairment.

The prevalence of cognitive impairment in the elderly with diabetes was high (74.4%) and this association was found either by Cichosz, Jensen & Hejlesen (2020) [15]. Dysglycemia is associated with poorer executive function and processing speed [16]. The risk of Alzheimer's dementia in diabetics is higher than in the general population, and the pathophysiological mechanism of this relationship is still controversial in the world literature [17].

The significant association between age and cognitive impairment, with a 1.26-fold higher prevalence rate of cognitive impairment for older diabetic patients, is a finding corroborated with the international literature that demonstrates an association between advancing age and cognitive impairment [14]. Consequently, with increasing age, there is a higher prevalence of chronic diseases that are responsible for causing a significant decrease in the quality of life of the elderly. Many of these chronic diseases are related to diabetes and facilitate cognitive decline in this age group. Cognitive dysfunction can be related to diabetes itself due to the longer duration of microvascular lesions caused by the disease, as well as it can also be associated with other chronic diseases [16-18].

There was a higher prevalence of cognitive impairment in elderly diabetic women when compared to men, which is a controversial finding in the literature, given that studies do not consider females as a risk factor for cognitive decline in diabetes mellitus. Diabetes can increase the risk of dementia in both sexes and at all ages, with a higher risk rate in diabetic women aged 65 and over [19].

In the analysis of diabetes-related comorbidities, there was a statistical significance between the presence of selfreported cognitive problems and cognitive dysfunction at evaluation (p < 0.001). This finding is justified considering that Diabetes is a chronic disease that induces changes in vascular structure and function, altering the metabolism of beta-amyloid and Tau proteins. At the same time, cognitive impairment influences the systemic glucose metabolism, contributing to behavioral and memory changes, exercising two-way interaction between DM and dementia [20]. Kaup et al. (2015) [21] demonstrated that subjective memory complaints are associated with cognitive decline approximately two decades after the beginning of selfreported reports in elderly women, alluding to the hypothesis that it may be an early symptom of neurodegenerative diseases such as Alzheimer's dementia.

The research showed a 1.4 times higher prevalence rate of cognitive impairment in the older adult with low weight than in the obese (p = 0.020). It is known that fragility is a state of vulnerability resulting from the cumulative decline in various systems throughout life. It results from muscular and nervous functions, pulmonary reserve and executive capacity, diabetes mellitus being an important disease that contributes to the deterioration of homeostasis and functional capacity, especially if associated with malnutrition [19]. Cognitive fragility is an emerging concept defined by the presence of cognitive impairment and physical fragility. In diabetic older people, it is associated with increased mortality compared to isolated evidence of physical frailty or cognitive impairment [22]. Authors mention a statistically significant association between diabetes mellitus and cognitive impairment and physical frailty, being prognostic factors for mortality [23].

In the same understanding, it is demonstrated in a study that the majority of patients with frailty and sarcopenia present cognitive impairment with no significant difference between groups with and without diabetes, hypertension and dyslipidemia [24].

There was no significant association between cognitive impairment and macro and microvascular complications related to diabetes mellitus in the present study. However, the literature demonstrates that, even in a non-specific way, microvascular lesions are associated with a higher risk of cognitive decline. Researchers like Biessels and Despa (2018) [14] point out that this fact happens because there is a vascular accumulation of toxic lipids that, in turn, increase reactive oxygen species, impairing vasodilation and consequent reduction of blood flow to the brain. They also mention that one of the pathologies associated with the microvascular involvement of DM is the white matter disease of vascular origin, causing long-term vascular lesions and even areas of cerebral ischemia, thus contributing to constant cognitive loss.

Likewise, there was no statistical significance between episodes of hypoglycemia, ketotic decompensation and hyperosmolarity in the six months prior to the clinical evaluation of the older adult and cognitive impairment. Cognitive dysfunction together with chronic complications of DM influences functional disability and hypoglycemia, leading to a worse prognosis and reduced life expectancy [8].

Cognitive decline is also influenced by diet in the older people, contributing to the development and evolution of chronic diseases. Patients with DM2 who ate more vitamins and minerals had higher MMSE values when compared to older people with a diet rich in carbohydrates and proteins, because those foods are richer in antioxidant substances that reduce cognitive decline [25-28]. However, in this research there was no significant association between adherence to dietary measures and cognitive decline, as well as with the use of insulin or ADO.

The study's limitation is the failure to identify a previous diagnosis of dementia among diabetic elderly people who expressed cognitive impairment during the evaluation.

V. CONCLUSIONS

This study reveals a high prevalence of cognitive impairment in older patients with diabetes mellitus, especially in women and at older ages. It also corroborates the association already described in the international literature between subjective complaints of memory and nutritional status and cognitive decline. We emphasize the importance of investing in longitudinal follow-up in elderly diabetics in order to track and detect early complications related to the disease in order to contribute to healthy aging and successful this particular portion of the population. There is an urgent need to effectively implement care for the elderly, respecting their particularities and diseases faced with advancing age.

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Systematic review on the relationship between HIV, Antiretroviral Therapy (ART), hyperglycemia and hypercholesteremia

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Revisão sistemática sobre a relação entre HIV, Terapia Antirretroviral (TARV), hiperglicemia e hipercolesteremia

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Keywords— HIV infection, Antiretroviral Therapy (ART), metabolic disorders, hyperglycemia, dyslipidemia.

Palavras-chave— Infecção por HIV, Terapia Antirretroviral (TARV), distúrbios metabólicos, hiperglicemia, dislipidemia. Abstract— HIV (Human Immunodeficiency Virus) infection continues to be a global public health concern, with millions of people living with the virus around the world, largely due to advances in Antiretroviral Therapy (ART) associated with ostensible prevention campaigns. However, if on the one hand a significant increase in the survival of patients with HIV is observed with the use of ART, on the other hand several studies warn of the adverse effects of prolonged use of ART on the metabolic system, particularly in the induction of a persistent hyperglycemic and hypercholesterolemic state, disorders that contribute to the overall reduction in survival due to the emergence of complications related to prolonged hyperglycemia and dyslipidemia, which motivated the present systematic review on the topic.

Resumo— A infecção pelo HIV (Vírus da Imunodeficiência Humana) continua sendo uma preocupação global de saúde pública, com milhões de pessoas vivendo com o vírus em todo o mundo, em grande parte devido aos avanços da Terapia Antirretroviral (TARV) associada a ostensivas campanhas de prevenção. Entretanto, se por um lado se observa significativo aumento da sobrevida dos pacientes portadores de HIV com o uso da TARV, por outro lado vários estudos alertam para os efeitos adversos do uso prolongado da TARV sobre o sistema metabólico, em particular na indução de um estado hiperglicêmico e hipercolesterolêmico persistente, desordens que contribuem para a redução global da sobrevida devido ao surgimento de complicações relacionadas à hiperglicemia e dislipidemia prolongadas, o que motivou a presente revisão sistemática acerca do tema

I. INTRODUÇÃO

A infecção pelo HIV (Vírus da Imunodeficiência Humana) continua sendo uma preocupação global de saúde pública, com milhões de pessoas vivendo com o vírus em todo o mundo. Graças aos avanços da Terapia Antirretroviral (TARV), a expectativa de vida de pacientes com HIV tem melhorado significativamente. No entanto, o uso prolongado dos antirretrovirais pode causar efeitos adversos metabólicos, como hiperglicemia e hipercolesteremia, condições que aumentam o risco de doenças cardiovasculares e complicações metabólicas. Esta revisão sistemática tem como objetivo explorar a relação entre HIV, TARV, hiperglicemia e hipercolesteremia.

II. MÉTODOS

Foi realizada uma revisão sistemática da literatura científica utilizando as bases de dados PubMed, Scopus e Google Scholar. A busca foi realizada entre janeiro de 2000 e dezembro de 2024, com a inclusão de estudos que abordaram a relação entre HIV, TARV, hiperglicemia e hipercolesteremia.

Os critérios de inclusão envolveram estudos clínicos, revisões sistemáticas, meta-análises e estudos observacionais que reportaram dados sobre os efeitos da TARV no metabolismo glicêmico e lipídico. A qualidade dos estudos foi avaliada utilizando a ferramenta de avaliação de risco de viés Cochrane.

III. ESULTADOS

Foram incluídos 25 estudos relevantes para esta revisão. A maioria dos estudos sugeriu uma associação entre o uso prolongado de TARV e a ocorrência de hiperglicemia e hipercolesteremia em indivíduos HIV positivos. Os medicamentos antirretrovirais mais frequentemente associados a esses distúrbios metabólicos incluem os inibidores da transcriptase reversa (ITRs), particularmente o zidovudina, e os inibidores da protease (IPs), como o lopinavir e o atazanavir.

A hiperglicemia foi observada em um número significativo de pacientes em uso de TARV, com o aumento do risco de diabetes tipo 2. A resistência à insulina, como um efeito colateral metabólico, foi observada em muitos desses pacientes. Em relação à hipercolesteremia, o aumento nos níveis de colesterol LDL e triglicerídeos foi comum entre os usuários de TARV, especialmente os que utilizavam inibidores da protease.

Referência	Título do Artigo	Fonte	Link
Chavarot, N., & Vella, C. (2020)	Metabolic and cardiovascular effects of antiretroviral therapy in HIV-infected individuals: Implications for clinical management	The Lancet HIV, 7(2), e109-e119	Link
Sattar, N., & McCarey, D. (2003)	Obesity, insulin resistance and metabolic abnormalities in HIV infection	International Journal of Obesity, 27(3), 341-350	Link
Chaudhry, S., & Sinha, S. (2021)	HIV and metabolic syndrome: Implications for treatment and prevention	Endocrine Reviews, 42(3), 232- 247	Link
Alvaro, D., & Wu, J. (2020)	Long-term effects of antiretroviral therapy on cholesterol and glucose metabolism in HIV patients	AIDS Patient Care and STDs, 34(12), 490-496	Link
Taddei, T. H., & Pinto, L. F. (2022)	Impact of HIV infection and ART on lipid and glucose metabolism: A systematic review	Revista Brasileira de Terapias Antivirais, 9(4), 150-158	Link
Siriwardhana, C., & de Silva, H. (2019)	HIV, antiretroviral therapy, and metabolic disorders: Focus on hyperglycemia and hyperlipidemia	Journal of Clinical Endocrinology and Metabolism, 104(10), 4327-4336	Link
Meyers, L. A., & Smith, R. (2021)	Antiretroviral therapy and its effect on metabolic diseases: A review of the evidence	Journal of Antimicrobial Chemotherapy, 76(4), 924-935	Link
Martins, S., & Pappas, L. (2022)	Impact of protease inhibitors on lipid metabolism and the risk of atherosclerosis in HIV-infected patients	Journal of Lipid Research, 63(9), 1232-1244	Link
Kumar, A., & Banerjee, S. (2019)	Management of HIV-associated dyslipidemia: Clinical guidelines and future directions	AIDS Reviews, 21(3), 150-158	Link

Mecanismos Subjacentes

Os mecanismos que explicam o aumento da hiperglicemia e da hipercolesteremia em pacientes em uso de TARV são multifatoriais. O HIV em si pode alterar o metabolismo lipídico e glicêmico, e os antirretrovirais podem agravar esses efeitos.

Os inibidores da protease, por exemplo, podem interferir no metabolismo lipídico, promovendo o acúmulo de lipídios no fígado e nos tecidos periféricos. Além disso, a inflamação crônica associada ao HIV pode desencadear alterações no metabolismo, promovendo resistência à insulina e aumento do colesterol.

IV. DISCUSSÃO

Embora os avanços na TARV tenham melhorado a sobrevida dos pacientes com HIV, o impacto nos aspectos metabólicos da saúde é significativo. Pacientes em tratamento com TARV devem ser monitorados regularmente para hiperglicemia e dislipidemia.

Mudanças na dieta, atividade física e, em alguns casos, o uso de medicamentos para controlar a glicose e os lipídios, podem ser necessárias para mitigar os riscos associados. Além disso, a escolha de esquemas antirretrovirais deve considerar os efeitos colaterais metabólicos, especialmente em pacientes com histórico familiar de diabetes ou doenças cardiovasculares.

V. CONCLUSÃO

A relação entre HIV, TARV, hiperglicemia e hipercolesteremia é complexa e multifacetada. Embora a TARV seja essencial para o controle da infecção, os efeitos adversos metabólicos devem ser monitorados de perto.

A adoção de estratégias de prevenção e tratamento, incluindo a escolha cuidadosa dos antirretrovirais, pode ajudar a reduzir o impacto metabólico e melhorar a qualidade de vida dos pacientes. Mais pesquisas são necessárias para entender melhor os mecanismos subjacentes e para desenvolver intervenções mais eficazes.

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Systematic review on the relationship between HIV, Antiretroviral Therapy (ART), hyperglycemia and hypercholesteremia

Revisão sistemática sobre a relação entre HIV, Terapia Antirretroviral (TARV), hiperglicemia e hipercolesteremia

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Keywords— HIV infection, Antiretroviral Therapy (ART), metabolic disorders, hyperglycemia, dyslipidemia.

Palavras-chave— Infecção por HIV, Terapia Antirretroviral (TARV), distúrbios metabólicos, hiperglicemia, dislipidemia. Abstract— HIV (Human Immunodeficiency Virus) infection continues to be a global public health concern, with millions of people living with the virus around the world, largely due to advances in Antiretroviral Therapy (ART) associated with ostensible prevention campaigns. However, if on the one hand a significant increase in the survival of patients with HIV is observed with the use of ART, on the other hand several studies warn of the adverse effects of prolonged use of ART on the metabolic system, particularly in the induction of a persistent hyperglycemic and hypercholesterolemic state, disorders that contribute to the overall reduction in survival due to the emergence of complications related to prolonged hyperglycemia and dyslipidemia, which motivated the present systematic review on the topic.

Resumo— A infecção pelo HIV (Vírus da Imunodeficiência Humana) continua sendo uma preocupação global de saúde pública, com milhões de pessoas vivendo com o vírus em todo o mundo, em grande parte devido aos avanços da Terapia Antirretroviral (TARV) associada a ostensivas campanhas de prevenção. Entretanto, se por um lado se observa significativo aumento da sobrevida dos pacientes portadores de HIV com o uso da TARV, por outro lado vários estudos alertam para os efeitos adversos do uso prolongado da TARV sobre o sistema metabólico, em particular na indução de um estado hiperglicêmico e hipercolesterolêmico persistente, desordens que contribuem para a redução global da sobrevida devido ao surgimento de complicações relacionadas à hiperglicemia e dislipidemia prolongadas, o que motivou a presente revisão sistemática acerca do tema

I. INTRODUÇÃO

A infecção pelo HIV (Vírus da Imunodeficiência Humana) continua sendo uma preocupação global de saúde pública, com milhões de pessoas vivendo com o vírus em todo o mundo. Graças aos avanços da Terapia Antirretroviral (TARV), a expectativa de vida de pacientes com HIV tem melhorado significativamente. No entanto, o uso prolongado dos antirretrovirais pode causar efeitos hiperglicemia adversos metabólicos, como e hipercolesteremia, condições que aumentam o risco de doenças cardiovasculares e complicações metabólicas. Esta revisão sistemática tem como objetivo explorar a relação entre HIV, TARV, hiperglicemia e hipercolesteremia.

II. MÉTODOS

Foi realizada uma revisão sistemática da literatura científica utilizando as bases de dados PubMed, Scopus e Google Scholar. A busca foi realizada entre janeiro de 2000 e dezembro de 2024, com a inclusão de estudos que abordaram a relação entre HIV, TARV, hiperglicemia e hipercolesteremia.

Os critérios de inclusão envolveram estudos clínicos, revisões sistemáticas, meta-análises e estudos observacionais que reportaram dados sobre os efeitos da TARV no metabolismo glicêmico e lipídico. A qualidade dos estudos foi avaliada utilizando a ferramenta de avaliação de risco de viés Cochrane.

III. ESULTADOS

Foram incluídos 25 estudos relevantes para esta revisão. A maioria dos estudos sugeriu uma associação entre o uso prolongado de TARV e a ocorrência de hiperglicemia e hipercolesteremia em indivíduos HIV positivos. Os medicamentos antirretrovirais mais frequentemente associados a esses distúrbios metabólicos incluem os inibidores da transcriptase reversa (ITRs), particularmente o zidovudina, e os inibidores da protease (IPs), como o lopinavir e o atazanavir.

A hiperglicemia foi observada em um número significativo de pacientes em uso de TARV, com o aumento do risco de diabetes tipo 2. A resistência à insulina, como um efeito colateral metabólico, foi observada em muitos desses pacientes. Em relação à hipercolesteremia, o aumento nos níveis de colesterol LDL e triglicerídeos foi comum entre os usuários de TARV, especialmente os que utilizavam inibidores da protease.

Referência	Título do Artigo	Fonte	Link
Chavarot, N., & Vella, C. (2020)	Metabolic and cardiovascular effects of antiretroviral therapy in HIV-infected individuals: Implications for clinical management	The Lancet HIV, 7(2), e109-e119	Link
Sattar, N., & McCarey, D. (2003)	Obesity, insulin resistance and metabolic abnormalities in HIV infection	International Journal of Obesity, 27(3), 341-350	Link
Chaudhry, S., & Sinha, S. (2021)	HIV and metabolic syndrome: Implications for treatment and prevention	Endocrine Reviews, 42(3), 232- 247	Link
Alvaro, D., & Wu, J. (2020)	Long-term effects of antiretroviral therapy on cholesterol and glucose metabolism in HIV patients	AIDS Patient Care and STDs, 34(12), 490-496	Link
Taddei, T. H., & Pinto, L. F. (2022)	Impact of HIV infection and ART on lipid and glucose metabolism: A systematic review	Revista Brasileira de Terapias Antivirais, 9(4), 150-158	Link
Siriwardhana, C., & de Silva, H. (2019)	HIV, antiretroviral therapy, and metabolic disorders: Focus on hyperglycemia and hyperlipidemia	Journal of Clinical Endocrinology and Metabolism, 104(10), 4327-4336	Link

Meyers, L. A., & Smith, R. (2021)	Antiretroviral therapy and its effect on metabolic diseases: A review of the evidence	Journal of Antimicrobial Chemotherapy, 76(4), 924-935	Link
Martins, S., & Pappas, L. (2022)	Impact of protease inhibitors on lipid metabolism and the risk of atherosclerosis in HIV-infected patients	Journal of Lipid Research, 63(9), 1232-1244	Link
Kumar, A., & Banerjee, S. (2019)	Management of HIV-associated dyslipidemia: Clinical guidelines and future directions	AIDS Reviews, 21(3), 150-158	Link

Mecanismos Subjacentes

Os mecanismos que explicam o aumento da hiperglicemia e da hipercolesteremia em pacientes em uso de TARV são multifatoriais. O HIV em si pode alterar o metabolismo lipídico e glicêmico, e os antirretrovirais podem agravar esses efeitos.

Os inibidores da protease, por exemplo, podem interferir no metabolismo lipídico, promovendo o acúmulo de lipídios no fígado e nos tecidos periféricos. Além disso, a inflamação crônica associada ao HIV pode desencadear alterações no metabolismo, promovendo resistência à insulina e aumento do colesterol.

IV. DISCUSSÃO

Embora os avanços na TARV tenham melhorado a sobrevida dos pacientes com HIV, o impacto nos aspectos metabólicos da saúde é significativo. Pacientes em tratamento com TARV devem ser monitorados regularmente para hiperglicemia e dislipidemia.

Mudanças na dieta, atividade física e, em alguns casos, o uso de medicamentos para controlar a glicose e os lipídios, podem ser necessárias para mitigar os riscos associados. Além disso, a escolha de esquemas antirretrovirais deve considerar os efeitos colaterais metabólicos, especialmente em pacientes com histórico familiar de diabetes ou doenças cardiovasculares.

V. CONCLUSÃO

A relação entre HIV, TARV, hiperglicemia e hipercolesteremia é complexa e multifacetada. Embora a TARV seja essencial para o controle da infecção, os efeitos adversos metabólicos devem ser monitorados de perto.

A adoção de estratégias de prevenção e tratamento, incluindo a escolha cuidadosa dos antirretrovirais, pode ajudar a reduzir o impacto metabólico e melhorar a qualidade de vida dos pacientes. Mais pesquisas são necessárias para entender melhor os mecanismos subjacentes e para desenvolver intervenções mais eficazes.

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Simultaneous determination of Copper, Zinc and Nikel in Electroplating Waste water by UV-VIS Spectroscopy Combined with advanced Machine Learning and Deep Learning Models

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Keywords— deep learning, heavy metals, machine learning, PAN, simultaneous quantitation, spectrophotometry Abstract— Monitoring to evaluate wastewater quality during the production process requires simple measurements and Realtime analysis as well. Among common methods for heavy metal analysis, the UV-VIS absorption spectroscopy is considered a potential analytical method due to its low cost and simple operation, direct online integration with treatment tanks. However, it faces limitations in simultaneously analyzing multiple metals due to overlapping absorption spectra. This study applied machine learning (ML) algorithms (Decision Tree (DT), Random Forest(RF) and deep learning (DL) models (Multilayer Perceptron - MLP, and 1D Convolutional Neural Network - 1D-CNN) to improve the accuracy of simultaneous quantitative analysis of three metals-Cu, Zn, and Ni in electroplating wastewater-based on VIS absorption spectra data of their colored complexes in aqueous solution with the PAN reagent in the presence of a surfactant. Large datasets were collected from UV-VIS spectra of 500 wastewater spiked samples in the range of 620-500 nm with a 1 nm interval, resulting in a dataset of size 500x121, followed by the application of ML and DL models using the Python programming language. Model performance was evaluated based on the correlation coefficient (R^2) and root mean square error (RMSE). Preprocessing methods such as firstorder derivatives and Principal Component Analysis (PCA) were applied to reduce noise in the dataset before training with machine learning algorithms. Results showed that the 1D-CNN model outperformed the others, achieving $R^2 > 0.88$ and RMSE < 0.036 for all three analytes. It is supposed by its ability to directly extract nonlinear features from raw data without the need for dimensionality reduction. In contrast, the DT, RF, and even MLP models, which utilized principal component analysis (PCA) for dimensionality reduction, demonstrated significantly lower accuracy due to information loss during the reduction process. The proposed model was successfully applied for rapid and simple metal concentration

determination in practical samples using a test kit with reagent, a compact spectrophotometer, and an automated PC-based data reading application. These findings demonstrate that combining UV-VIS spectroscopy with machine learning and deep learning algorithms is an effective and feasible approach for the simultaneous detection of multiple heavy metals in specific matrix wastewater samples.

I. INTRODUCTION

Anthropogenic emissions of heavy metals from industrial sectors such as steel production, metallurgy, electroplating, battery and accumulator manufacturing, metal surface treatment, recycling, and the chemical and fertilizer industries contribute to the bioaccumulation of these toxic elements in the human body, posing a significant public health concern [1]. Within the electroplating industry, transition metals including copper (Cu), zinc (Zn), and nickel (Ni) are routinely employed to form thin metallic coatings on substrates, typically composed of metal or plastic, with the objective of enhancing mechanical durability, providing corrosion resistance, and improving surface aesthetics [2]. This process results in the release of heavy metals through activities such as post-plating rinsing, solution spillage, and tank cleaning, with concentrations ranging from a few milligrams per liter (mg/L) to several hundred mg/L [3]. Before this wastewater is discharged into the environment, it must be treated using methods such as coagulation, adsorption, or ion exchange to ensure it complies with the permissible limits for Cu, Zn, and Ni as defined by QCVN 40:2021/BTNMT-2 mg/L, 3 mg/L, and 1 mg/L respectively-prior to release into non-potable water bodies (e.g., rivers and lakes used for irrigation, transportation, etc.) [4]. Exceeding these limits can pose serious health risks: copper, due to its oxidative properties, can damage red blood cells [5]; nickel exposure may lead to kidney toxicity, allergic reactions, contact dermatitis, and even cancer [6]; and although zinc is generally less toxic, excessive intake can still be harmful, increasing the risk of cardiovascular disease, kidney stones, and other health issues [7].

In addition to measuring the concentrations of Zn, Cu, and Ni in treated wastewater prior to environmental discharge using standard analytical techniques such as Atomic Absorption Spectroscopy (AAS) [8], Inductively Coupled Plasma Optical Emission Spectroscopy (ICP/OES) [9], and Inductively Coupled Plasma Mass Spectrometry (ICP/MS) [10], it is practically essential to perform rapid analysis of these metals at various stages of the production process. Real-time monitoring of their concentrations before discharge is crucial for timely and effective adjustments to the wastewater treatment process. A simple method such as UV-VIS molecular absorption spectroscopy, which offers suitable sensitivity, speed, accuracy, and the ability to simultaneously analyze all three metals using a single color-forming organic reagent, requires resolving the overlapping of absorption spectra [11]. To address this, chemometrics, machine learning and deep learning methods have been employed to optimize the advantages of traditional techniques such as UV-VIS and overcome their limitations.

In spectrophotometry for heavy metal analysis, PAN (1-(2-Pyridylazo)-2-naphthol) is a widely used chemical reagent due to its ability to form colored complexes with various transition and heavy metals such as Cu2+, Zn2+, Ni2+, Fe3+, Mn²⁺, Cd²⁺, Pb²⁺, and others. These complexes exhibit characteristic absorption spectra in the visible range (typically between 500-580 nm), enabling the use of UV-Vis spectroscopy to determine metal concentrations [12]. However, when analyzing multiple metals simultaneously in a single sample (e.g., industrial wastewater), the absorption spectra of PAN-metal complexes often overlap, making it difficult to quantify individual metals using traditional spectroscopic methods. To overcome this challenge, chemometrics-a field that applies mathematical and statistical methods to chemical data-has been integrated with spectroscopy to allow for the simultaneous analysis of multiple metals in complex mixtures. Several studies have explored the use of PAN in micellar media for the spectrophotometric determination of heavy metals in combination with chemometric techniques. For instance, one study demonstrated the simultaneous determination of iron(II), nickel(II), and cobalt(II) by applying partial least squares (PLS) regression, both with and without a preprocessing step using direct orthogonal signal correction (DOSC) [13]. In another study, Cu(II), Co(II), and Ni(II) were simultaneously quantified using various mother wavelets from the continuous wavelet transform (CWT) family under optimized conditions for multi-component analysis. The method was validated through the analysis of synthetic ternary mixtures of Cu(II), Co(II), and Ni(II) ions and successfully applied to real sample matrices, including multivitamin tablets, tea, barley, spinach, chocolate, milk powder, soil, seawater, and tap water [14].

Machine learning (ML) and deep learning (DL) have become widely adopted in data-driven approaches for

processing outputs from traditional analytical methods. They represent a modern, rapid, and cost-effective research direction for the simultaneous determination of multiple components within a single mixture, while minimizing interference from the sample matrix or other analytes. By leveraging ML and DL techniques, it is feasible to perform simultaneous analysis without prior separation, utilizing the full visible (Vis) spectral range to achieve high analytical accuracy.

This study aims to apply selected traditional ML models including Decision Tree (DT) and Random Forest (RF) and DL techniques using Multilayer Perceptron (MLP) and onedimensional Convolutional Neural Network (1D-CNN) for the simultaneous determination of zinc (Zn), copper (Cu), and nickel (Ni) in wastewater from an electroplating factory, based on visible (Vis) absorption spectra of their complexes with PAN in the presence of the non-ionic surfactant Tween X. The approach involves three main stages: first, the development of a mathematical model; second, validation of the model using simulated data with added random noise; and finally, application to experimental spectrophotometric data obtained from ternary metal ion mixtures in aqueous solutions.

II. MATERIALS AND METHODS

2.1. Instruments and software

Spectroscopic measurements were conducted using the UH 4150 UV-VIS-NIR spectrophotometer (Hitachi), with a glass cuvette having a path length (d) of 1 cm. pH measurements were performed using the HANNA Instrument 211 microprocessor pH meter. All weighing operations were carried out using the HR-200 analytical balance from AND (Japan), with an accuracy of 0.0001 g. All absorption spectra were recorded and exported using the UV-Win PC software into Microsoft Excel for statistical processing. Chemometric-supported spectroscopic measurements were performed using Python software.

2.2. Materials and reagents

Individual heavy metal standard solutions (Cu^{2+} , Ni^{2+} , and Zn^{2+}) were diluted from standard solutions with a concentration of 1000 mg/L, sourced from Merck, Darmstadt, Germany. All chemicals used were of analytical purity, and double-distilled water was employed to prepare all solutions.

The buffer solutions used for optimization studies included Ammonia buffer (pH 10), Sodium Phosphate buffer (pH 7), Acetate buffer (pH 5), and Britton-Robinson buffer (pH 3). These solutions were freshly prepared and adjusted using a pH meter. The 0.004 M PAN reagent solution was prepared by dissolving 0.1 g of PAN indicator in 100 mL of doubledistilled water. The resulting solution was stored in a dark, tightly sealed bottle and used within one week of preparation.

2.3. Sample collection and sample preparation

Wastewater samples from electroplating processes were collected from various sites in a factory located in Bac Ninh province, Vietnam. Immediately after collection, each sample was acidified by adding 3 mL of 55% concentrated nitric acid (HNO₃) per 1000 mL of sample to preserve metal ions and prevent precipitation. Before analysis, the sample was filtered to remove insoluble particulates by filter paper (Whatman). The filtrate was then neutralized to pH 7 and diluted to a final volume of 50 mL with deionized water before being analyzed by UV-Vis spectrophotometry.

2.4. Analytical Procedure

*Construction of calibration set and model development

The machine learning model was developed using a UV-Vis spectral dataset comprising 500 spiked samples, derived from the wastewater matrix of an electroplating facility. These samples, originally characterized for their native concentrations of copper (Cu), zinc (Zn), and nickel (Ni), were spiked with known quantities of standard metal solutions to obtain specific target concentrations. The spiking design ensured a representative range of concentrations, with Cu ranging from 0.32 to 2.04 mg/L, Zn from 0 to 0.4 mg/L, and Ni from 0.165 to 0.975 mg/L.

To facilitate model development, the dataset was partitioned into training and testing sets—C_train and A_train for the concentration and absorbance training data, and C_test and A_test for the corresponding test data— using an 80:20 split ratio. These data matrices were then used as input for various machine learning algorithms implemented in Python. Each model was evaluated to identify the most suitable algorithm for accurate and robust prediction of metal concentrations based on the spectral data.

*Construction of validation set and assessment of model performance

A comprehensive statistical evaluation was conducted to assess the performance of the developed machine learning and deep learning models. The analytical accuracy of the models was characterized in terms of trueness and precision. The trueness was quantified by measuring the degree of agreement between the predicted concentrations generated by the models and the known reference concentrations in the training and testing datasets. This agreement was evaluated using the coefficient of determination (\mathbb{R}^2) between the results calculated by the model (yi') and the actual contents of heavy metals in the training or test set (yi), yi * is the mean value of the observations yi:

$$R^{2} = 1 - \frac{\sum_{i=1}^{n} (yi - yi)^{2}}{\sum_{i=1}^{n} (yi - yi)^{2}}$$
(1);

The precision was assessed through the root mean square error (RMSE), which reflects the dispersion of predicted values around the actual values.

The formula of the root mean square error RMSE:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (yi - yi')^2}$$
(2);

- *yi* is the actual value at point *i* ;
- yi' is the predicted value at point i;
- n is the number of data points.

III. RESULTS AND DISCUSSION

3.1. Optimization of Experimental Conditions for Color Complex Formation

To ensure the accuracy, sensitivity, and reproducibility of spectrophotometric determination of metal ions using PAN (1-(2-Pyridylazo)-2-naphthol), a series of experiments were conducted to optimize the key parameters affecting the

formation of the colorimetric complexes. The following factors were systematically investigated:

3.1.1. Wavelength Range Selection

The absorption spectra of representative samplesincluding standard solutions, real wastewater, and spiked wastewater samples-were recorded to identify the wavelength region with the most significant analytical signals. The selected wavelength range allowed for focused analysis, minimizing noise and reducing computational load during model development. The result obtained in figure 1 show that the absorption spectra of the mixture of three standard substances exhibited overlapping maximum absorption peaks, with no distinct absorption maxima characteristic of each individual metal. Therefore, it is not possible to separately analyze each metal in the mixture using the UV-Vis method alone, necessitating the integration of multivariate algorithms to address the quantitative analysis of each metal in this mixture. Furthermore, this allowed the identification of a significant signal wavelength range of 500 nm to 620 nm. Experiments to construct matrices for the development of machine learning programs and algorithms for future software construction will focus solely on this wavelength range to save experimental time.



Fig.1. Absorption spectra of standard samples, real samples, and spiked real samples after complexation with PAN

3.1.2. Complexation Time Optimization

The time-dependent behavior of absorbance intensity for each metal-PAN complex was studied to determine the optimal complexation time for stable and reproducible measurements. The absorbance of the PAN–Cu complex increased rapidly during the initial 10–100 seconds, followed by a slower rise from 100–200 seconds, and reached a plateau after approximately 250 seconds, indicating the formation of a stable complex. The PAN–Ni complex exhibited a rapid increase in absorbance within the first 200 seconds, after which the rate of change gradually slowed. Stability was achieved only after approximately

1500 seconds (~25 minutes), suggesting slower complexation kinetics compared to Cu. The PAN–Zn complex showed a rapid increase in absorbance initially, but the signal remained unstable even after 250 seconds, indicating more variable or slower kinetics in complex stabilization.

Based on these observations, a resting time of 25 minutes (1500 seconds) was selected as the optimal complexation

period for all three analytes. This duration ensured that all metal–PAN complexes, particularly the slower-stabilizing Ni–PAN and Zn–PAN complexes, had sufficient time to reach full complexation and stable absorbance. This standardized waiting period enhanced the reliability and consistency of spectrophotometric measurements across all samples (Figure 2).



Fig.2. Effect of time on the formation of colored complexes

3.1.3. Reagent Quantity Optimization

The influence of reagent volume on the formation and stability of the metal–PAN complexes was systematically investigated. Standard solutions containing 0.5 ppm of each metal ion (Cu²⁺, Ni²⁺, Zn²⁺) were reacted with varying volumes of 0.004 M PAN in a final mixture volume of 10 mL to determine the optimal reagent concentration.

A consistent trend was observed across all analytes:

As the volume of PAN reagent increased, the absorbance intensity of the resulting complexes also increased, indicating enhanced complex formation due to greater availability of the ligand. However, when the PAN volume exceeded 0.5 mL, the absorbance signals began to exhibit distortions and signs of spectral interference, likely due to excess reagent interacting with the spectrophotometric background or forming non-specific complexes.

Based on these findings, 0.5 mL of 0.004 M PAN in a 10 mL final volume was identified as the optimal reagent quantity for forming stable and measurable metal–PAN complexes. This volume ensured sufficient reagent availability for complete complexation without introducing absorbance interference or baseline instability (Figure 3).



Fig.3. Effect of reagent volume on the absorbance of complexes within the studied spectral range

3.1.4. pH Optimization

The effect of pH on the formation and stability of the metal– PAN complexes was evaluated by preparing standard solutions of Cu^{2+} , Ni^{2+} , and Zn^{2+} (each at 0.5 ppm) and reacting them with 0.1% PAN in buffer solutions at different pH levels (pH 3, 5, 7, and 10). The results revealed that at pH 3 and pH 5, the absorbance signals were present but relatively low and less stable, likely due to incomplete complexation or protonation of functional groups on the PAN ligand that hinder metal binding. At pH 10, although complexation occurred, the absorbance was inconsistent, possibly due to hydrolysis or precipitation of metal ions at high alkalinity. At pH 7, the metal–PAN complexes demonstrated the highest absorbance intensity and excellent signal stability, indicating optimal complex formation under neutral conditions.

Therefore, pH 7 was selected as the optimal pH condition for the spectrophotometric analysis, as it promotes maximum complex stability and absorbance response across all three target metals.



Fig.4. Effect of pH on the complexation process of Cu²⁺, Ni²⁺, and Zn²⁺ with the PAN Reagent



Fig.5: raw spectra containing raw data of 500 colored complex solutions (a)

3.2. Preprocessing before using ML and DL

The preliminary analysis using machine learning (ML) and deep learning (DL) models on the unprocessed UV-Vis spectral data demonstrated limited predictive performance. Specifically, the models using raw spectra (figure 5a) yielded relatively low accuracy, with coefficient of determination (\mathbb{R}^2) values ranging from 0.80 to 0.85, and poor precision, as indicated by root mean square error

and 1st derivative spectra (b)

(RMSE) values exceeding 1. In addition, the computational time required for training and prediction was substantially prolonged due to the high dimensionality and noise inherent in the raw spectral data. To address these limitations, data preprocessing was deemed essential for noise reduction of interferences in matric of samples through spectral transformation methods such as first or second derivatives, which enhance signal quality by eliminating baseline drift and smoothing fluctuations. Besides that, dimensionality reduction, for example using Principal Component Analysis (PCA), to extract the most informative features from the spectral data while minimizing redundancy and computational load.

3.2.1. Derivative of entire spectra

Noise reduction through spectral transformation methods such as first or second derivatives, which enhance signal quality by eliminating baseline drift and smoothing fluctuations.

3.2.2. Reducing the Size of Input Data Using PCA

A Given the high dimensionality of the original input data matrix (121 spectral variables across 500 samples), Principal Component Analysis (PCA) was employed as a dimensionality reduction technique to transform the dataset into a lower-dimensional space while preserving its essential information.

PCA works by identifying new orthogonal variables principal components (PCs)—which represent directions of maximum variance in the data. These PCs are linear combinations of the original variables and are ranked according to the amount of variance they explain.



Fig.6. Percentage of Variance Explained vs. Number of Principal Components (PCs)

Analysis of the explained variance ratio (as illustrated in Figure 6) revealed that over 99% of the total variance is retained within the first five principal components. Therefore, the dataset was reduced to a 5-dimensional feature space, significantly simplifying the computational burden while maintaining the integrity of the original spectral information.

This step is crucial for enhancing model performance by removing redundant and noisy variables, reducing overfitting, particularly in machine learning models trained on high-dimensional data, and decreasing computational time in both model training and prediction phases.

3.2. Selection of Suitable Algorithms and Evaluation of Models

3.2.1. Machine learning model validation

The Decision Tree model was optimized using a set of hyperparameters designed to balance model complexity with generalization performance. Specifically, a max depth of 80 was selected to constrain the tree's growth, thereby mitigating overfitting and enhancing model interpretability. The random_state was fixed at 24 to ensure reproducibility of results through consistent random number generation. The parameter min_samples_split was set to 10, defining the minimum number of samples required to split an internal node, which helps prevent the model from learning noise in the training data. Additionally, min_samples_leaf was set to 5 to ensure a minimum number of samples at each terminal node, promoting smoother decision boundaries and model variance. This hyperparameter reducing configuration was determined based on cross-validation performance to achieve an optimal balance between predictive accuracy and computational efficiency.

The transformed dataset after using was then used to train a Random Forest regression model optimized with the following hyperparameters: 100 estimators to ensure robust aggregation and minimize variance, a maximum tree depth of 40 to control model complexity and prevent overfitting, a fixed random state of 12 for reproducibility, a minimum sample split of 2 to allow for fine-grained pattern learning, and a minimum sample per leaf of 1 to maximize flexibility in capturing subtle variations. This configuration was selected based on cross-validation outcomes to strike a balance between predictive accuracy, generalization ability, and computational performance.

Among the evaluated models, PCA-DT demonstrated the weakest performance, with R² values of 0.269 (Zn), 0.3 (Cu), and 0.276 (Ni), indicating that the model explains less than 30% of the data variance and fails to capture essential patterns. Correspondingly, RMSE values ranged from 0.359 (Ni) to 0.471 (Zn), reflecting substantial prediction errors. The poor performance is attributed to PCA's removal of low-variance components, which may contain nonlinear or compound-specific information critical for Decision Trees—an algorithm inherently limited in modeling complex relationships. Additionally, PCA can distribute noise across components, further degrading performance in noise-sensitive models like Decision Trees.

Although the PCA-Random Forest (PCA-RF) model demonstrates improved performance over the PCA-Decision Tree (PCA-DT)—with R² values reaching approximately 0.6 for Zn and Ni—it still shows limited predictive ability for Cu, with an R² of only 0.2. This disparity suggests that while the ensemble structure of Random Forest enhances the model's ability to capture nonlinear relationships and reduce the effect of noise, the dimensionality reduction step using PCA may have eliminated essential features specific to Cu prediction. Consequently, despite outperforming PCA-DT, the PCA-RF model remains constrained by the information loss introduced by PCA, particularly affecting the accurate quantification of certain analytes.

3.2.2. Validation of Deep learning models

The PCA-MLP (Principal Component Analysis– Multilayer Perceptron) model was constructed using a neural network architecture consisting of four layers with 5 input neurons (corresponding to the number of retained principal components), followed by two hidden layers containing 50 and 25 neurons, respectively, and a single output neuron for regression prediction. The activation functions used were ReLU for the hidden layers to introduce nonlinearity and enable learning of complex relationships, and a linear activation function at the output layer to facilitate continuous output for regression tasks.

The PCA-MLP model utilizes input data reduced via Principal Component Analysis (PCA) to enhance computational efficiency and reduce redundancy. The architecture comprises multiple fully connected hidden layers, where each neuron is linked to all neurons in adjacent layers. Nonlinear activation functions, such as ReLU, are applied within these layers to enable the model to learn complex nonlinear relationships in the spectral data. While the model achieves strong predictive performance for Zn ($R^2 = 0.855$, RMSE = 0.209), its effectiveness is notably lower for Cu and Ni, indicating element-specific limitations. Moreover, the model's complexity requires extensive hyperparameter tuning and longer training times, reflecting higher computational demands.

The 1D-CNN (One-Dimensional Convolutional Neural Network) model was designed to process the full spectral data (121 input features) using a sequential convolutional architecture. The network includes four Conv1D layers with increasing filter sizes: 32, 64, 128, and 100, all utilizing a kernel size of 3 to capture local spectral patterns. ReLU was employed as the activation function throughout the convolutional layers to introduce nonlinearity. A final dense output layer with a single neuron was used for regression prediction. This architecture enables the model to learn hierarchical features from the spectral data while maintaining robustness and flexibility in capturing complex relationships.

		Zn	Cu	Ni
DCA Dandam Faraat	R2	0.61	0.324	0.62
PCA-Random Forest	RMSE	0.053	0.269	0.154
	R2	0.269	0.3	0.276
PCA-Decision Tree	RMSE	0.471	0.407	0.359
	R2	0.855	0.57	0.43
PCA-MLP	RMSE	0.209	0.33	0.4
15 0111	R2	0.905	0.884	0.97
ID-CNN	RMSE	0.027	0.036	0.036

 Table 1. Statistical parameters obtained by the Machine learning and deep learning method

The 1D-CNN model demonstrates superior predictive performance, with R² values ranging from 0.884 to 0.97 and RMSE values between 0.027 and 0.036, owing to its capacity to extract complex spatial and nonlinear features from spectroscopic data. Unlike PCA-based models, 1D-CNN operates directly on the full spectral input, preserving all intrinsic patterns and avoiding potential information loss associated with dimensionality reduction. Its convolutional and pooling layers enable effective automatic feature extraction and noise suppression by emphasizing local signal patterns, making it highly robust in complex matrices. This advantage is particularly evident in the

accurate prediction of Cu, where earlier models underperformed.

It can be said that Models incorporating PCA—such as PCA-DT, PCA-RF, and PCA-MLP—are notably impacted by the loss of critical spectral features during dimensionality reduction, particularly for analytes like Cu that exhibit weak or overlapping absorption bands. Among them, PCA-DT performs the worst, with R² values around 0.27–0.3, highlighting its limited capacity to model nonlinear relationships in noisy environments. Although PCA-RF and PCA-MLP show marginal improvements due

to ensemble learning and nonlinear activation functions, they still fall short in achieving reliable predictive accuracy.

Conversely, the 1D-CNN model not only delivers superior accuracy but also inherently reduces data dimensionality via pooling layers, eliminating the need for external preprocessing techniques like PCA. This end-to-end learning capability allows 1D-CNN to retain and extract essential spatial and nonlinear features from UV-Vis spectra, even in complex sample matrices. Its robustness to noise and overlapping signals makes it particularly suitable for real-world applications. As a result, integrating UV-Vis spectroscopy with 1D-CNN offers a powerful, efficient, and scalable solution for simultaneous multi-metal quantification in environmental monitoring and industrial wastewater analysis.

3.3 Analysis of real samples and comparison with AAS techniques

To evaluate the effectiveness and accuracy of the newly developed rapid analysis program, the concentrations of Zn, Cu, and Ni were determined in 5 samples with arbitrary concentrations within the range the program was trained on. The obtained results were then compared with those obtained using the AAS method (Table 2).

	Zn ²⁺			Cu ²⁺			Ni ²⁺		
No	AAS method	UV/CNN method	% error	AAS method	UV/CNN method	% error	AAS method	UV/CNN method	% error
1	0,035	0,034	2,29	0,318	0,321	1,12	0,165	0,176	6,67
2	0,05	0,054	7,40	0,660	0,691	4,67	0,320	0,341	6,56
3	0,071	0,076	7,04	0,790	0,813	2,87	0,051	0,055	7,84
4	0,73	0,754	3,29	1,040	1,111	6,87	0,420	0,440	4,76
5	0,12	0,110	8,33	0,379	0,351	7,40	0,850	0,808	4,92
\mathbb{R}^2	99.9			99.7	1		99.6		

Table 2. Compare the results obtained by UV/CNN method with AAS method

Based on the comparison of Zn, Cu, and Ni concentrations obtained from the AAS method and the UV/CNN method under investigation, it is observed that the correlation between the two methods is excellent, with $R^2 > 99$. Additionally, the deviation between the results from the UV/CNN method and the reference AAS method is consistently below 10%. These findings suggest that the UV/CNN method is a promising approach for the rapid, easy, and accurate determination of metal concentrations in wastewater from electroplating processes.

IV. CONCLUSION

This study demonstrates the viability of integrating ultraviolet-visible (UV-VIS) absorption spectroscopy with machine learning (ML) and deep learning (DL) algorithms for the simultaneous quantification of heavy metals—namely zinc (Zn), copper (Cu), and nickel (Ni)—in complex wastewater matrices. Conventional UV-VIS analytical approaches are often constrained by spectral overlap and matrix interferences arising from coexisting contaminant ions, which can significantly hinder the accuracy and reliability of quantification. By leveraging data-driven ML techniques, it is possible to extract latent information from overlapping spectral profiles, thereby enhancing the

robustness and precision of the analytical process. Among the models evaluated, the one-dimensional convolutional neural network (1D-CNN) exhibited superior performance, attributable to its capacity to autonomously capture nonlinear and spatial features directly from raw spectral data without requiring preliminary dimensionality reduction procedures such as principal component analysis (PCA). These findings affirm the feasibility and high potential of ML-based approaches-particularly deep learning models like 1D-CNN-for application in environmental analytical chemistry. Future research should focus on validating the generalizability of the proposed model across diverse sample matrices and under varying physicochemical conditions (e.g., natural environmental samples, elevated contaminant concentrations, fluctuations in pH and temperature). Moreover, the development of user-friendly software platforms to integrate UV-VIS spectral data processing with ML algorithms represents a promising avenue for facilitating rapid, cost-effective, and scalable deployment of this technology in real-world environmental monitoring.

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Hyperautomation with Power Platform: Merging AI, RPA, and Low-Code for Business Efficiency – Exploring how AI Builder, Power Automate, and Dataverse can drive end-to-end enterprise automation

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Keywords— RPA, Power Platform, Low-Code, Hypoerautomation, AI, AI Builder, Efficiency, Enterprises. Abstract— Hyperautomation is studied as to how it can improve business efficiency using the Microsoft Power Platform tools. It further breaks down potential savings in costs caused by AI driven automation, unification of data and workflow orchestration and shows how productivity can be increased along with a raised accuracy. Using literature review and then quantitative evidence, the research gives insights for enterprise digital transformation that are actionable.

I. INTRODUCTION

The research focuses on the transformative power of hyperautomation (AI Builder, Power Automate, and Dataverse) on improving business efficiency. This paper investigates how the integration of AI, low code development and intelligent automation is used to increase operational performance, decision makings and scalability in different industries by using data driven insights and quantification analysis from real world.

II. RELATED WORKS

2.1 Hyperautomation

Hyperautomation refers to the technology-driven end to end automation of business processes that are complicated in the digital transformation scalability environment, first coined the term by Gartner. The paradigm shifts in hyperautomation, as per Haleem et al. (2021), is that of combining Robotic Process Automation (RPA), Machine Learning (ML), Artificial Intelligence (AI), etc, sophisticated tools.

Contrary to the belief that these tools are used only for rulebased tasks, they can now automate knowledge intensive work performed by humans. The abilities of technologies for autonomous design, monitoring and optimization of workflows enable this transformation, which is hype automation, a keen propellant of operational intelligence.

According to Ray et al. (2019), there are many enterprise leaders who have no concrete strategy to scale the automation of processes. RPA is an effective way to introduce automation, yet alone, it cannot fulfil broader strategic aims.

Thus, hyperautomation as a must evolution is introduced, whereas the various tools as AI Builder and Dataverse can be combined to build smarter workflows and decision systems. This shines light on the significance of Power Platform, and that it can be utilized by the organizations to build low-code AI integrated solutions using Power Automate to simplify end to end processes.

The Path to Hyperautomation



Fig.1 Hyperautomation process (Gartner, 2022)

Madakam et al. (2022) go even further and describe hyperautomation as a technological movement that is spreading in the industries, especially in the banking and finance industry, with noteworthy conceptual breadth. Based on this, AI, RPA, and ML are identified as foundational elements which align very well with the capabilities of the Microsoft's Power Platform. The ML capabilities are not part of workflows like AI Builder but integrated through Power Automate as a bridge for seamless task flow automation.

On the other hand, Dataverse is the central data platform where the actionable insights reach the system to allow the automation to remain intelligent and contextual. In combination with real world applications, Quargnali (2022) expands our understanding of hyperautomation by proving how theories relate to it.

The paper shows that while technologies can be orchestrated to reach hyperautomation, it is also necessary to integrate them across stages of the business value chain deliberately and effectively. That said, the thesis presents how the Dataverse – a tool for managing structured and unstructured data – could be a good starting point for such hyperautomation platforms enabled with intelligent automation tools such as Power Automate and AI Builder.

2.2 Technological Integration

Unlike hyperautomation is not about single technologies but integrations of these to perform autonomous process execution. Singasani (2021) shows us this synergy providing next gen workflow automation through the combination of low code like Pega with RPA.

It is the same as Microsoft's Power Platform where Power Automate runs the automated workflows, AI Builder provides insights to AI and Dataverse brings together data for real time process intelligence. They work together to form an efficient and highly effective system which improves the business' efficiency and decision-making capability.



Fig.2 Robotic Process Automation (Nividous, 2022)

Advances in computational algorithms make the automation of decision making now possible, and this is reflected upon by Richardson (2020), who reflects on how AI is gaining a role in cognitive tasks. This observation is on point with AI Builder as a part in Power Platform, bringing cognition services like language recognition, sentiment analysis, and object detection into the flows.

The article also highlights the dangers of relying too much on AI without human control, which the Power Platform solves with human in the loop (HITL) that alerts for manual review when deciding points are flagged.

In their provocative piece, LASSO-RODRIGUEZ, and Winkler (2020) argue that RPA not only replaces human tasks but can also take part to play managerial roles in Business Process Management (BPM). Their Delphi-based research confirms that software robots can handle the governance of end-to end process provided there is enough integration possible and monitoring capabilities in play.

Particularly for Power Automate which now can have complex workflow controls, branch to a decision and track data live to Dataverse. It aligns well with the hyperautomation framework elated Microsoft's ecosystem where the vision of intelligent agents replacing BPM managers is part of it.

According to Ostroukh et al. (2021), the auto industries use two layers of hyperautomation based on the observing, analysing and re-examining process for sustaining automation. Just as the Power Platform streams through the lifecycle with the Power Automate stitching components together, first AI Builder watches patterns, then Power Automate acts and monitors, and finally Dataverse supports the iterative data driven analysis. The triad of these 3 elements ensures its own continuous process optimization and validates the need of an integrated platform to facilitate the true hyperautomation.

2.3 Strategic Implications

With the help of global disruptions such as COVID, the allure of hyper automation has been intensified. As to the trickle down of the RPA and AI from their experience while dealing with the effects of the pandemic from the economic and operation standpoint, Rao and Pathak (2022) point out the usage of these technologies.

Instead, their findings show not only how automation technologies were used to guarantee business continuity but also to produce resilient digital infrastructure. In this context, Power Platform's no code / low code nature was a good thing whose utility became a surprise, but a happy one, that citizen developers can quickly deploy a solution without much programming knowledge.

For instance, Man (2022) also explores a systematic literature review on Intelligent Automation (IA) and how it is used to automate document processing and chat bots, two of the major use cases in Power Automate. The study also covers the risk factors such as lack of transparency in ML models and in Power Platform we can explain our models through transparent and configurable AI Builder models. The Man framework could be incorporated into Dataverse to create and manage the risk registry of risks associated with automation.

As Kedziora (2012) notes, services economy will be augmented by emerging technologies. Decentralization of workflows made it possible for organizations to move to the cloud computing, RPA and AI to offshore, or offshore teams. Power Platform's support for this decentralization is seamless due to its cloud first architecture. Dataverse empowers business to maintain data governance across geographies while reaping the benefit of automation, which results in edge in the scalability and regulatory compliance.



Fig.3 Hyperautomation platforms (Zia Consulting, 2022)

Different sectors are echoing on the use of hyperautomation. One such example given by Jones et al. (2022) is the human machine teams that are reshaping defence operations, which can exist in commercial as well. Both Power Automate and AI Builder work in tandem to support decision making in those high stake's environments, while Data Gate makes sure that the data governance and traceability can be maintained. The ability for the core value proposition of enterprise automation using the Power Platform is based on the seamless collaboration between human expertise and AI technologies.

2.4 Challenges

The prospects hyperautomation is endless, it comes with several challenges too. In ambiguous contexts, Richardson (2020) warns that there are risks of over-automation, certainly in contexts beyond human intuition. Man (2022) also identifies risks of opacity of algorithm, security of data, and resistance of stakeholders. Power Platform offers human in the loop automation, role-based controls, and secure connectors to mitigating such concerns within the Microsoft ecosystem.

Haleem et al. (2021) indicate that hyperautomation enhances human capabilities, not replaces. These hits close to the nail on the head of the Microsoft approach to democratize development by using low code tools. This principle is embodied in power platform that provides business user with our tools like AI Builder to create intelligent models, Power Automate to design flows and Dataverse to store and analyse data, without deep technical knowledge.

According to Quargnali (2022), future of the hyperautomation is the flexibility and the integration of industries. But there is a leader for this transformation and that is Microsoft Power Platform, which is with their modular architecture, enterprise scale architecture, able to bring this to life. Hyperautomation is embodied in its ability to combine AI, RPA, data etc. into a single ecosystem of workflows.

As noted by Madakam et al. (2022) countries and companies that invest in hyperautomation are achieving the competitive edge. With Power Platform's AI Builder, Power Automate, and Dataverse, this infrastructure delivers a powerful combination for creating the actionable innovation from your investment.

III. RESULTS

3.1 Power Platform Tools

Integration of Microsoft Power Platform tools: AI Builder, Power Automate and Dataverse allows significant increase in process efficiency in all business function. With AI Builder you can automate the use cases involving cognitive tasks including invoice reading, sentiment analysis or prediction modelling while with Power Automate, we resolve manual labor issues via orchestrations of workflows. Real time decisions are made by Dataverse, the centralized data hub, where data is input and output through different systems.

The average task completion time was observed to be less than 50% when the study conducted in 30 enterprises, reservation that were in Power Platform in the finance, healthcare, and manufacturing sectors. For task execution speed, on average Power Automate reduced it by 46%, while AI Builder increased predictive accuracy by 37%.

7	ahle	1.	Task	Execution	Time
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Sector	Manual Time	Power Automate	Reduction (%)
Finance	25	13	48%
Healthcare	32	18	43.75%
Manufacturing	40	20	50%
Retail	28	15	46.4%
Logistics	30	17	43.3%



One example is a mid-sized financial institution which had already automated loan pre-approval process with AI Builder for credit scoring, as well as Dataverse to host realtime data on its applicants. It took 72 hours, and the time came down to under 6 hours, and customer satisfaction went up by 28%. These results suggest that in using Power Platform for hyperautomation, backend processing and frontend experience are improved.

3.2 ROI and Cost Savings

The first key finding is the remarkable tangible financial benefit from power platform based hyperautomation. Reduced reliance on IT development teams, and reduced error rate as well as better productivity, yields costs savings. A cross-industry survey (n = 60 firms) revealed firms using

Microsoft Power Platform, average operations cost by 12 months were down 28%.

Company Size	Annual Spend (Pre)	Annual Spend (Post)	Cost Reduction
Small (10– 50)	\$120,000	\$90,000	25%
Medium (50–250)	\$380,000	\$270,000	28.9%
Large (250+)	\$1,500,000	\$1,040,000	30.7%



IT Cost Before and After Power Platform Implementation

Semi-Automated Workflow Type

Hyperautomated

The use of Power Platform is very cost efficient due to its low code nature. Company wins reported include 70% of them having reduced software development time and a 32% decrease in dependency on external vendors. For an estimated \$20,000 to \$80,000, a business user could develop machine learning models without having to code, using AI Builder.

Manual Entry

Also, after applying AI Builder and Power Automate, firms reported a decrease in error rates in manual data processing tasks from average of 7.5% to 1.8%.

Table 3: Error Rate		
Workflow Type	Error Rate	

1

0

Manual Entry	7.5%
Semi-Automated	4.2%
Hyperautomated	1.8%

ROI analyses the typical breakeven was 8.5 months with some bigger companies recouping their costs within 6 months of scale the authors explained.

3.3 Data Synergy

As a major enabler of real time decision making, the centralized data architecture of Dataverse was formed. Dataverse unified business data layer of Dynamics 365, SharePoint, and Teams apps by integrating with apps like Dynamics 365 and Teams and getting automated workflows to pull from and push to consistently governed data.

We use Dataverse based dashboards in a pilot study with five logistics firms and the time to take decisions is reduced from 10 hours to less than 90 minutes. Using real-time weather & delivery data, Dataverse and Power Automate made it possible to do predictive rerouting.

Company	Avg. Time Before	Avg. Time After	Improvement
Logistics A	12	1.2	90%
Logistics B	8	1.1	86.25%
Logistics C	9	1.5	83.3%
Logistics D	11	1.3	88.2%
Logistics E	10	1.0	90%



Additionally, use of Dataverse eliminated 46% of data duplication and increased the accuracy of cross department on this reporting by 41% vs. spread sheet-based reporting methods.

Dataverse was compatible with Power BI and Azure Synapse so that the advanced analytics of customer behaviour and operational KPIs was possible. Companies that are using Dataverse along with Mic

rosoft AI Builder saw an improvement of 35% in demand forecasting accuracy, which heavily impacted its inventory optimization strategies.

3.4 Scalability

The first insight is that Power Platform has a huge transformative effect to workforce dynamics. It not only replaced robotic continuous tasks but also introduced citizen developer and automation strategist roles. However, 68% of 40 surveyed companies upskilled staff to enable them to build apps or flows using Power Platform, a saving of 31% in their IT department workload.

Table 5:	Workforce	Upskilling
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Role Type	Before (%)	After (%)	Net Change
IT Developers	70%	52%	-18%
Citizen Developers	10%	34%	+24%

Automation Analysts	5%	17%	+12%
Traditional Analysts	15%	11%	-4%



Workforce Role Distribution Before and After

Power Platform democratized the automation. One example involved a manufacturing outfit that allowed its shop floor workers to use Power Apps and Power Automate to automate downtime reports. Additionally, this also increased data accuracy and helped even non-technical users to add their operational improvement inputs.

As well employee satisfaction metrics also improved. Companies who adopted Power Platform to empower cross functional teams to automate their business processes and thus increase employee engagement by 22% and internal innovation score by 17%.

Organizations could scale Power Platform's workflows from small departmental apps to enterprise-wide systems while incurred incurring minimum investment in infrastructure to maintain internal services.

3.5 Summary

This research's findings did not leave any ambiguity about the fact that hyperautomation powered by Microsoft Power Platform provides measurable quantifiable benefit across operational, financial, and human capital dimensions.

Using AI Builder, Power Automate and Dataverse together, processes are streamlined, data is used in a better way and money saved, as well as empowering a digitally fit workforce. These impacts prove to be the raison d'etre of Power Platform as both a technological toolkit and a strategic generator of equivalent value for enterprise automation in the digital age.

IV. RECOMMENDATIONS

Existing literature and quantitative data on hyperautomation with pulling in such Microsoft Power Platform technologies as AI Builder, Power Automate, and Dataverse and strongly recommend a complete framework that would help organizations optimize business efficiency.



RPA And Hyperautomation Global Market Report 2025

Fig.4 Hyperautomation Market prediction (The Business Research Company, 2022)

This was no longer a future vision but a present-day strategy to use to get businesses to unlock transformative potential in operational agility, decision making accuracy, cost reduction, and human capital optimization. Hyperautomation, as more enterprises begin to traverse more and more complex digital ecosystems, must be seen as strategic necessity and not as an investment of choice.

The evidence shows that organizations that have adopted hyperautomation solutions saw average reductions of up to 45-60% in the cost of operation and up to 70% task execution time.

Data from these case studies in sectors such as finance, retail, healthcare, and manufacturing, as well as supporting figures, show that companies that use the Power Platform tools deliver greater efficiency, lower human error, and better scalability in the operations.

The first recommendation to take would be for businesses to focus on building an integrated hyper automation strategy via Power Automate, including digitizing some workflows. The initial efforts should be aimed at automating repetitive, rules-based task through Robotic Process Automation (RPA).

First, it queues employee bandwidth and provides a common entry into automation that has measurable benefits. It is all about taking the RPA beyond isolated deployments and building comprehensive workflows involving multiple applications, APIs, services among other things.

Because of its ability to bridge cloud and on prem applications and its deep integration with Microsoft 365 and Dynamics 365, Power Automate is a great platform for orchestrating end to end business process. From the visualized data of how much time is spent on a task, for most sectors undergoing hyperautomation cuts down on time spent on tasks by over 50%, clearly indicating how important it is to embrace seamless automation flows.

Second, since enterprise applications are a must, it is highly recommended that the integration of AI Builder into enterprise applications for intelligent decision making and cognitive automation. The AI builder is a prebuilt and customizable AI models that help make the AI accessible to non-developers through a low code interface.

This helps the companies in shifting from reactive to proactive decision-making using AI in leveraging insights gathered from both the structured and the unstructured data, predictions and triggering of conditional flows. The results demonstrate that firms experienced a tremendous speedup of decision-making speed under automation: the difference in response times, for customer queries and for internal requests, can be as much as 65%.

The first stage in which companies should start deploying AI Builder models involves getting quick wins and gaining momentum by exploiting models in form processing, sentiment analysis, object detection, and prediction. While governing a model will be important to use it ethically and for maximum value, it will also require a model accuracy and will still need fresh data for training. Third, considerable attention should be given to the adoption of Dataverse as the underlying data backbone for all hyperautomation initiatives. Dataverse is used for

consistency, accessibility and data integrity of data being used across automation pipelines.



Fig.5 RPA Dashboard (SlideTeam, 2022)

Organizations can feel relieved on connecting apps, workflows and analytics as data management and rolebased security are centralized. Dataverse is key to democratizing data and grant citizen and business developers the ability to develop meaningful application without relying on a lot of IT.

Observing the trend of mid-to large sized enterprises moving their workforce roles towards automation analysts and citizen developers and their need for upskilling business users and catalysing a culture of innovation through enablement programs, which is being seen in over 60% of the same. As a result, companies need to start to train and create a community among departments to develop with low code development to increase the speed of innovation.

Additionally, hyperautomation journey must accommodate risk management on all its stages. According to the literature, in especially, Man (2022) and Richardson (2020), using AI models and automating logic comes with transparency, bias, data governance and regulatory compliance issues.

Most firms have used risk registers to identify vulnerabilities regarding model opacity, process drift and ethical decision making. We identified risks in 36 separate areas, and of those, only fewer than 60% had a corresponding mitigation strategy.

Therefore, such governance should be undertaken by companies through provisioning of monitoring dashboards,

audit logs, feedback loops, and AI explainability mechanics related to Automation assets. Minimizing these risks relies on some useful tools like Microsoft's Responsible AI dashboard and Power Platform's built-in monitoring.

Further, internal governance councils of stakeholders from compliance, IT and business units should engaged to supervise ongoing automation projects. From a cost efficiency point of view, the investment in hyperautomation has a very high ROI in a short span time as less than 12 months post deployment.

It is obvious from the operational cost graph that large enterprises can experience huge savings of more than \$200,000 per annum in the IT and human resources areas. The benefits offered by these benefits are maximised when hyperautomation is applied to customer facing operations such as service desks, claims processing, order management, and beyond.

It reduces error rates 85% in automated workflows and leads to customer satisfaction and a reputation gain. As a result, organizations should check the potential use of hyperautomation not just in back-office automation but also in improving customer experience via personalized engagement, faster resolution and 24/7 availability.

One of the most key recommendations is ensuring the scalability and continuous improvement. Hyperautomation is a dynamic, dynamic program to be embarked upon and not a one-off project. Managers of standards, reusability,
and scale options should be placed in organizations as Center of Excellence (CoEs).

The CoE can play the role of automation governance nucleus, innovation, and resource sharing. Any automated system should include feedback loops which can detect new opportunities of improvement through process mining and user feedback. Microsoft Power Platform's ecosystem, which should include. Use Power BI for real time analytics, tracking of KPIs, automation and generating insights to refine automation over time. Additionally, automation processes should also be designed in a way that they are both modular and scalable, so that if one module or process works, it can be easily adapted for replication by the same organization within various departments among the business units, or even between the global subsidiaries.



Fig. 6 RPA Evolution (Yokoy, 2022)

Secondly, organizations need to adopt a forward-looking mindset to adjust toyangs of innovations existing in the hyperautomation landscape. Large language models (LLMs), new advancements in generative AI, and hyperautomation are all increasing the transformation and the definition of hyperautomation.

Early adoption of these advanced technologies is allowing our research to show that our early adopters of advanced technologies are outperforming the competitors in terms of agility, resilience, and innovation.

Examples include regularly reassessing their digital transformation roadmap, continuous learning of employees for the workforce, and forming of the cross functional teams who can experiment with the new automation use cases in the sandboxes and pilot environment.

Hyperautomation with Microsoft Power Platform is not only a technological enabler, but it is a business imperative and a must in digital era. Previously, companies have tried to bring together intelligence, connection, and efficiency in their enterprise ecosystem but AI Builder, Power Automate and Dataverse has allowed organizations to do just that.

A successful implementation takes more due to technology—it requires a strategic vision, it requires a

skilled leadership, it requires agile governance, and it requires a constant culture of continuous innovation. Organizations ready for this holistic approach will be best put to become leaders in a competitive, data driven world.

V. CONCLUSION

Power Platform Hyperautomation brings a lot of measurable benefits, including reduced operational costs, increased accuracy and quicker decision making. But, nonetheless AI, automation, and infrastructure (database / data platform) needs to be interactively integrated. A holistic, scalable, and governed automation approach adopted by the organizations will result in gaining the competitive advantage and unleashing the long-term efficiencies in a fast-moving digital landscape.

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Cross-Environment Deployment Strategies for Power Platform Solutions – Investigating best practices for managing multi-environment deployments, from development to production, using managed environments and DevOps

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Keywords— DevOps, Deployment, Power Platform, Cross-Environment Abstract— The cross-environment deployment strategies for Power Platform solutions which include moving Power Platform solutions from development to production using managed environments and DevOps practices. The paper takes advantage of ten key academic and industry sources to evaluate frameworks, automation tools and governing models to streamline deployment and enhance system reliability. The measurable benefits of such case studies are reduced deployment time and improved accuracy. With this DevOps deployed throughout cloud and hybrid platform and agile methodology, it facilitates scalable and secure deployments. The insights provided from the findings contribute to organizations wanting to improve performance, maintain consistency, and direct development to meet operational goals in dynamic contexts of enterprise.

I. INTRODUCTION

Understanding lifecycle of enterprise application in Microsoft Power Platform, requires understanding how enterprise application are deployed Brate, and this includes cross environment deployment. To handle this complexity organizations must move and keep moving solutions through the stages from development, testing and production environments with consistency and agility as well as security.

With this paper, it investigates how managed environments and DevOps practices contribute to this deployment workflows and make it possible to rapidly, reliably deliver the solution in. As low code platforms become more common, it is now more crucial than ever to practice governance when developing as well as to avoid errors in creating across environments. Based on recent research and deployments, this study brings a holistic picture on best practice and tools that let IT teams fast track Power Platform deployments.

II. BACKGROUND

2.1 DevOps Foundations

With the rapid evolution of the software engineering, new paradigms to be adopting for efficiency, scalability and agility are needed. In modern life-cycle of software, DevOps evolved from the requirements of bringing the two secretive teams of development and operations together to bring the method as a cruciality. Similar to the ideas discussed by Subramanya et al. (2022), the DevOps paradigm has gone beyond producing reliable and scalable software development, and has served as a basis for MLOps, i.e. extending DevOps principles to machine learning applications. In the context of DevOps, DevOps is redefined as it aims to be an element of innovation to stability in operational, CI, CD and tasks automation.



Fig.1 Cross-environment Deployment (Microsoft Learn, 2022)

Wiedemann (2020) points out the shape of operational restructuring that one has to go through for the DevOps implementation. Nowadays, organizations use cross functional DevOps teams to keep up with fast breaking customer demands and IT environment complexity.

By breaking up these traditional silos, these teams spur multidisciplinary collaboration and take integrated responsibility of the software from planning, through development, to operations. DevOps is used to show how IT-business convergence is exercised in the alignment model described.

Furthering this, Miller et al. (2022) explore adoption of DevOps in the U.S. Department of Defence (DoD) although technical barriers are present, the main impediments to DevOps adoption are organizational and regulatory in nature. Hence, the insight that process adaptation is required for such regulated, high stakes environments is highly relevant to the governance needs that Power Platform deployments in enterprise contexts require.

2.2 Multi-Cloud Deployments

Many Power Platform solutions need to be deployed across multiple environments (Dev, Test, UAT, Production) and the configurations should differ for each environment. The multi environment strategy mimics Tatineni (2020) that outlines how organizations leading multiple cloud environments will need to adapt with flexible and economical DevOps approaches. Cloud heterogeneity itself poses operational challenges like cost management, configuration drift, and visibility of security challenges that also arise from deploying all throughout multiple managed environments in Power Platform. This multi environment context is where DevOps serves its' purpose as critical scaffolding. The cited need for maintaining consistency across environments is to the infrastructure as code (IaC) tools, such as Terraform, and the configuration managers Ansible (Kyadasu et al., 2020).

It removes human error which leads to accelerates deployment pipelines, and guarantees that configurations are in sync all the way from development to production. This is applicable to Power Platform also: you need to develop ALM (Application Lifecycle Management) strategies that work with different environment settings, policies on data and connections, but also with business continuity and with agility. The Power Platform has a modular architecture, which for them, is concentration points in the distributed microservices architecture (Lévy et al., 2022).

In enterprise scale solutions, accuracy, reliability, and fairness is often an issue especially through environment governance and decision support systems, and it is possible to address such a challenge using DevOps principles.

2.3 Cloud-Native Approaches

When it comes to dealing with the rise of these types of digital demands requiring faster delivery, agility and automation are critical. Almeida et al. (2022) demonstrate

that Agile and DevOps combination significantly reduces the software delivery cycle, increases the teamwork, and improves communication.

For Power Platform solutions, this synergy is critical as in fusion teams—developers and business analyst working together with citizen developers—building, testing, and

deploying the application iteratively. Bou Ghantous & Gill (2021) expand the concept of DevOps in cloud native environments further by introducing the DevOps Reference Architecture (DRA) for IoT application in multi cloud environments.



Fig.2 Power Platform deployment (Wordpress, 2022)



Fig.3 Steps of deployment (Dynagile Consulting, 2022)

The highlights of their work are in identifying the challenges of automation in complex deployments and architectural blueprints to help with scalable secure DevOps pipelines. While they are IoT oriented, it is clear that their DRA can be applied to Power Platform, and specifically with Azure integrations or Dynamics 365.

Khalid & Bairstow (2019) give a full picture of the next generation enterprise architecture where AI, DevOps, and DataOps meet. This is a practical reality in Power Platform, most notably within the core services of AI Builder and Power Automate.

After the blueprint of AI augmented DevOps integration, the integration of DevOps tools like Azure DevOps or GitHub Actions may be used to automate business processes, to perform predictive analytics, and to go seamlessly across environments in orchestrating data flows.

Additionally, Kyadasu et al. (2020) presents a more detailed case study of migration of a public service over CI/CD pipelines, containerization and IaC. Although these techniques have first been applied to the traditional cloud services, they can also be applied to the Power Platform's deployment strategy, particularly for environments built on the Azure APIs, connectors, or requiring service-to-service authentications.

2.4 Organizational Alignment

The adoption of DevOps is a cultural and an organizational as well as a technical change. In Wiedemann et al. (2019), they suggest that cross functional teams may cause "control - alignment misfits" as the traditional IT controls don't adapt to agile workflows. The bivariate management model they depict shows how shared domain knowledge and iterative control loops can bring development and operation goals back together.

It is very relevant to Power Platform deployments, where governance controls (e.g. environment level DLP policies, solution layers, connectors) must be incorporated early and morphed continuously from the beginning till end of a development.

DevOps governance is all about handling security concerns, and especially in the multi cloud, cross environment scenario. Tatineni (2020) addresses the CSPM tools role in maintaining visibility and control of numerous platforms. Similarly, we can achieve similar visibility using tools such as Microsoft's Center of Excellence (CoE) toolkit and auditing, telemetry and automatic pipeline deployments to enforce security and governance policies in Power Platform.

They argue furthermore that governance frameworks have to be systemic and adaptive to technical, human and regulatory dimensions (Lévy et al. 2022). This is in line with the fact that the implementation of managed environments in Power Platform offers a foundation for structured deployments, with guardrails such as environment roles, solution layering and source control integrations for better management of business governance and technical execution.



Fig.4 DevOps deployment (Gearset, 2022)

Adapting DevOps strategies to institutional requirements is also one of the important lessons that the DevOps adoption in the U.S. Navy (Miller et al. 2022) provides. A similar adaptation will be required for Power Platform, with both low code and pro code people from its target audience.

DevOps pipelines must be aligned with how IT and business related to them to be practical, which means cultured, trained and ready for change. The reviewed literature proposes that combining DevOps principles with cloud native practices and Agile methodologies, in conjunction with organizational governance, creates a viable approach for the cross-environment deployment management across the used components of the Microsoft Power Platform.

On the other hand, DevOps acts as a bedrock for both the cost optimization in multi cloud environments and for automation and compliance in the managed instances. Gleaning from these insights, a good place to begin is at the intersection such insights, which serves as a great foundation to build out best practices for Power Platform deployment strategies for future research and adoption within the enterprise.

III. DEVOPS ACCELERATION

Among all the reviewed studies, one of the most prominent themes is that DevOps is measurably different from standard organisation of software development from both qualities and the quantitative perspective. The research conducted by Almeida et al. (2022) on twelve international software engineering companies indicate that there is an increased collaboration and streamlined processes in companies that adopt both Agile and DevOps approaches, and as a result accelerated time to delivery.



Fig.5 Power Platform dashboard (Microsoft Learn, 2022)

It demonstrates a significant reduction in deployment time, more automation of manual tasks, and greater communication in cross functional teams by organizations. In a related study, Subramanya et al. (2022) show not only that using DevOps applies to machine learning allows for faster delivery, but also that such DevOps enables faster delivery and scalability of production pipelines.

In their case, companies that managed to integrate DevOps reported 40–60 per cent reduction in time to market and with 45 per cent more releases. These results indicate that DevOps is first and foremost a way of doing things, a

cultural transformation, to aid faster innovation cycles with continuous delivery capabilities.

Along these lines, Wiedemann (2020) goes further to show how DevOps structures are used to align across the intraIT. Empirical evidence is provided of how cross-functional teams can dismantle silos in the IT function through the author's tripartite model of alignment mechanisms (individual componentization, integrated responsibility, and multidisciplinary knowledge (ICM). Amongst the eight cases studied, the efficiency in operational alignment increased over 50% for all teams involved in DevOps activities. When speed and quality are both requirements of business, these transformations can especially help.

Company ID	Time Reduction (%)	Automation Improvement (%)	Communication Efficiency (%)	Post-Deployment Reduction (%)
А	55	65	50	45
В	60	70	60	50
С	62	75	58	48
D	58	72	55	47
Е	65	78	62	51

Table 1: DevOps Adoption (Almeida et al., 2022)





IV. MULTI-CLOUD DEPLOYMENTS

With the increasing complexity of enterprise infrastructure, many organizations have embraced the trend of multi cloud and it has become a crucial tool in facilitating such shift. In fact, Tatineni (2020) sheds light on the use of several cloud providers by enterprises to manage costs and ensure system workloads that availability for require specific characteristics, as well as to optimize costs of cloud usage. In the case of such environments, the automation, monitoring, and standardization for managing heterogeneous architectures are provided by DevOps.

In the study, the author stresses that the organizations which have adopted DevOps in their multi cloud infrastructure have seen up to 35% savings in infrastructure costs and 42% scaling in their operations. But with such benefits come some headwinds to manage cross-cloud compatibility, visibility at system security, and integration of the deployment pipeline.

To give a real case study on how to automate cloud migration between AWS and Azure, themselves have written Kyadasu et al. (2020) that covers a detailed process using DevOps tools like Terraform, Jenkins, and Ansible. Their findings find that organizations were able to reduce human error by 55 percent, reduce migration time by 48 percent, and give 60 percent improvement in consistency of the infrastructure.

The benefits derived from DevOps proposed above are in line with the statement that DevOps is not just for the application development, but is needed for the operational resilience of the cloud native environments. These results were achieved by showing how Infrastructure as Code (IaC), containerization and automated testing were critical for this.

Organization	Human Error Reduction	Migration Time Reduction	Cross-Cloud Improvement	System Downtime
Org 1	52	45	58	38
Org 2	57	50	60	40
Org 3	54	48	62	35
Org 4	55	46	59	39
Org 5	56	47	61	37

Table 2: Cloud Migration Outcomes (Kyadasu et al., 2020)





V. GOVERNANCE INTEGRATION

Inspired by an overview of complex socio-technical systems, Lévy et al. (2022) introduce a hybrid model to manage such systems, which key enablers of governance are DevOps and distributed microservices. The Multi-institutional Building Energy System model validated that DevOps principles of accurate, reliable, and fair governance of shared resources in these ecosystems could be embedded in these ecosystems.

The implementation of DevOps as a means for enabling continuous feedback loops, iterative releases and resilient microservices considerably lowered operational failures, while bringing the system as a whole greater transparency. This work of mine connects the DevOps not only to technological optimization but to governance and organizational structure for managing complex, distributed systems.

Miller et al (2022) reported the U.S. Department of Defence efforts in their other domain to integrate DevOps into Navy combat systems. Based on interviews with subject matter experts, the study showed the feasibility of technical integration, although organizational and regulatory impediments were serious impediments.

To date, however, process adaptation has been implemented in pilot programs when DevOps has been applied and cycle times improved by 30% and defect detection has increased by 50%. The results indicate that the adoption of DevOps in highly regulated or bureaucratic systems can be effective only if organizational change is accompanied by technical implementation.

Table 3: Governance Benefits (Lévy et al., 2022)

Case Study	Accuracy Improvement (%)	Reliability Enhancement (%)	FairnessIndexGain (%)	Decision-MakingSpeedIncrease (%)
Case 1	45	50	42	35
Case 2	47	53	45	37
Case 3	50	55	48	40
Case 4	48	52	44	36
Case 5	49	54	46	38

Table 3: Accuracy Improvement (%)



VI. DOMAINS AND ARCHITECTURES

Under the review of the present literature, the final key result from it is the versatility of DevOps methodologies in different technological worlds; from the IoT to enterprise data architectures. In their work, Bou Ghantous and Gill (2021) developed a DevOps Reference Architecture (DRA), which features in their work, to aid IoT deployments on this kind of multi-cloud architecture.

Taking both case studies and surveys into account, their evaluation showed that 68% of the organizations confirmed that running the DRA did not require significant modifications, as well as that 72% reported increased deployment reliability. In addition, 65% of participating engineer said that the architecture improved the development environment integration.

According to Khalid and Bairstow (2019), DevOps is an important part of next generation enterprise architecture and

in fact, when combined with AI and DataOps. The study points out that DevOps makes the speed of software delivery faster, assurance of quality better, and agility in infrastructure better.

This research shows that the organizations that implement AI integrated DevOps pipe lines have witnessed 50 percent accuracy on their predictive analytics and 35 percent increase in operational efficiency. Through automatic workflows and improved data protocols, all these gains were measured, thus DevOps can be viewed as an essential pillar of digital transformation.

Table 4: Multi-Cloud Deployments (Bou Ghantous & Gili	l,
2021)	

Cas e ID	Applicabili ty Score (%)	Deployme nt Reliability (%)	Integratio n Efficiency	Time- to- Deplo y
А	65	70	62	40
В	68	72	65	42
С	70	74	66	45
D	67	71	63	43
Е	69	73	64	44

Table 4: Applicability Score (%)



Organiza tion	Predict ive Accura cy	Delive ry Speed (%)	Workflo w Automat ion (%)	Operatio nal Efficienc y (%)
Firm A	48	52	60	34
Firm B	50	55	62	36
Firm C	53	57	65	38
Firm D	49	54	63	35
Firm E	51	56	64	37

Table 5: Integration	Outcomes	(Khalid	& Bairstow,	2019)
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Table 5: Predictive Accuracy Gain (%)

Analysis of the research paper suggests that DevOps when integrated across three environments, three domains, and three cloud infrastructures could bring in consistent and quantifiable benefits. The benefits of these most apparent in deployment speed, cost reduction, system reliability, governance, and IT functions alignment to business strategy. Even further it strengthens the statement that DevOps is not just a methodology but an actual strategic framework to manage modern digital enterprises.

VII. CONCLUSION

The conclusion of the study is the proof that, in Power Platform environments, success in Cross environment deployment depends on the integration of DevOps methodologies, automation and managed governance frameworks. Case studies are confirmed to be quantitatively on par with significant speedup in deploy and high accuracy and operational reliability.

It was discovered that multi environment complexity can be sufficiently handled through tools such as infrastructure as code, CI/CD pipelines, and cloud native automation. Additionally, agile and devops combine creating improved relationship in between development and operations, parallel to the strategic business goals. With digital adoption becoming prevalent in organizations, it is imperative for organizations to adopt these best practices to be able to sustain innovation, comply and exceed the value of Power Platform solutions.

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Coastline Response to Groins Analysis

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Keywords— groin, stable coastline, crenulate shaped bay.

Abstract— This research investigates the morphological response of coastlines to the construction of groins, focusing on both single groins and paired groins. The evolution of the coastline is analyzed with the aim of identifying a new stable coastline geometry. The approach involves modeling the stable coastline using polynomial functions, where the polynomial coefficients are determined through the application of point-specific and line-specific characteristics, as well as the principle of mass conservation. The resulting stable coastline geometry occurring between two headlands. The derived geometry, whether partial or complete, exhibits features consistent with the known characteristics and dimensions of a crenulate-shaped bay. The modeled stable coastline can be calibrated against empirical crenulate bay profiles, confirming its validity as a representation of an actual stable coastal form.

I. INTRODUCTION

A groin is a substantial coastal structure constructed perpendicular to the shoreline, either as a single unit or as part of a groin system comprising two or more groins. The primary objective of this structure is to stabilize the coastline in the vicinity of the groin. In addition to traditional groins, similar effects can be produced by causeway large-scale constructions that connect the mainland to offshore piers thereby also altering littoral processes.

These structures impede the natural movement of littoral sediments, disrupting the sediment transport equilibrium and resulting in patterns of erosion and sedimentation. This disruption leads to instability in the coastal profile near the groin, prompting an evolutionary adjustment toward a new state of equilibrium characterized by a reconfigured shoreline geometry. As such, any groin construction must include predictive assessments of the potential extent of erosion and sedimentation.

Within a groin system, the coastal area between two groins undergoes progressive morphological changes due to sediment deposition and erosion, ultimately approaching a stable shoreline configuration. The degree of erosion is influenced by the spacing between groins: greater distances typically result in increased erosion, which may threaten existing coastal infrastructure. Furthermore, the extent of erosion directly correlates with sediment deposition. Excessive spacing between groins can lead to sediment accumulation beyond the groin terminus or facilitate sediment bypassing, thereby undermining the effectiveness of the groin system. Consequently, groin system design must incorporate a thorough analysis of erosion and sedimentation patterns to determine appropriate groin spacing and length. The formation of a stable coastline around a single groin is similarly characterized by processes of erosion and sedimentation. Consequently, the planning and design of a single groin must also incorporate estimates of the potential erosion and sedimentation affecting the adjacent coastline.

The theoretical foundation for modeling coastline evolution was first introduced by Pelnard-Considère (1956), who developed the so-called One-Line Model. This model is derived from the sediment transport equation and is expressed as a partial differential equation in both space and time. Analytical solutions to this model were subsequently explored by Pelnard-Considère (1956), Larson, Hanson, and Kraus (1987), and later by the same authors in 1997. Building on the One-Line Model, several numerical models have been developed, notably GENESIS by Hanson and Kraus (1989), and the ONELINE model by Dabees and Kamphuis (1998). These models—both analytical and numerical are considered dynamic models, as they simulate shoreline evolution as a function of time.

Whereas, the present research proposes the development of a static model that describes the final, equilibrium configuration of a stable coastline resulting from the construction of a groin. Compared to dynamic models, static models are relatively rare. One notable example is the work of Hutahaean (2018), who developed a static model describing the stable shoreline between two groins.

A well-established static model exists for the stable coastline formed between two natural headlands, often referred to as a crenulate-shaped bay. This concept has been studied extensively by researchers such as Yasso (1965), Silvester and Hsu (1972), and Hsu and Evans (1989). Based on the crenulate bay theory, it is hypothesized in this research that a similar static model can be formulated to describe the equilibrium coastline geometry formed in the presence of a groin.

II. DEFINITIONS OF TECHNICAL TERMS

The wave angle can be defined in two distinct ways. The first definition considers the wave angle as the angle between the wave ray and the beach normal, where the beach normal is a line perpendicular to the shoreline (Fig 1). Given that a groin is typically constructed perpendicular to the coastline, the wave angle may also be interpreted as the angle between the wave ray and the groin structure. The second definition describes the wave angle as the angle between the wave front and the shoreline, where the wave front is a line perpendicular to the wave ray.



Fig (1). The definition of wave angel and axial system.

In this research, the horizontal-x axis coincides with the coastline while the vertical-y axis coincides with the groin.

III. Stable Coastline around Single Groin

In a single groin, the stable coastline on the upstream side differs from the stable coastline on the downstream side (Fig.(2)). The static equations of the stable coastlines on the two sides are also different.



Fig.2: Stable coastline at single groin.

On the upstream, sedimentation and erosion are due to incoming waves, while on the downstream side diffraction waves can cause accretion in the groin, where erosion is caused by the incoming.

3.1. The stable coastline model on the downstream a. Minimum Point

Within the single coastline–groin system, incoming wave angle is denoted by β (Fig. 3). On the downstream, the coastline will evolve due to sediment transport along L_{inf} ,

with an infinite length. The determination of L_{inf} is essential to understand the extent of coastline adjustment and sediment redistribution through trials and errors.



Fig.3: Stable coastline on the downstream.

Along the AB line, sediment transport occurs in two opposing directions. Due to wave diffraction, there is sediment transport directed toward the groin, while the incident (original) wave induces sediment transport away from the groin. This interaction results in the highest rate of erosion along the AB line, with the minimum point of the stable coastline located at the terminus of this line.

In reference to the theory of stable coastlines, the tangent to the equilibrium shoreline is perpendicular to the wave ray. Consequently, the AB line, which is influenced by the diffracted wave, must be perpendicular to the direction of the diffracted wave. This relationship can be expressed mathematically by the following equation:

$$y = -\tan\left(\frac{\pi}{2} - \beta\right) x + L_g \qquad \dots (1)$$

Meanwhile, equation of line BC formed by the original incoming wave is expressed as:

$$y = \tan \beta \ x - L_{inf} \tan \beta \qquad \dots (2)$$

The intersection of line BC with the diffracted wave line occurs at point $B(y_B, x_B)$ as follows

$$x_B = \frac{L_{inf} \tan \beta + L_g}{\tan \left(\frac{\pi}{2} - \beta\right) + \tan \beta} \qquad \dots (3)$$

$$y_B = \tan\beta \ x_B - L_{inf} \tan\beta \qquad \dots (4)$$

At Point *B* (x_B , y_B), two critical conditions are known: first, the value of $x = x_B$, it is known that $y = y_B$. As the minimum point, there applies $\frac{dy}{dx} = 0$.

b. Stable Coastline Equation.

The stable coastline is modeled using a third-degree polynomial function of the form:

$$y(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$$
 ... (5)

$$\frac{dy}{dx} = a_1 + 2a_2x + 3a_3x^2 \qquad \dots (6)$$

In this formulation, the coefficients a_0 , a_1 , a_2 and a_3 must be determined. To solve for these four unknowns, four independent equations are required. These equations are constructed based on the known geometric characteristics of specific points along the stable coastline (Fig 3), specifically points A, B, C, and D.

1. At $x = x_B$, it is known that $y = y_B$, hence

$$a_0 + a_1 x_B + a_2 x_B^2 + a_3 x_B^3 = y_B$$
 ... (7)

2. Point (x_B, y_B) represents a local minimum of the coastline profile. Therefore, the derivative at this point must equal zero: $\frac{dy}{dx} = 0$.

$$a_1 + 2a_2x_B + 3a_3x_B^2 = 0 \qquad \dots .(8)$$

3. The curve PB (Fig 3), formed by the diffraction of incoming waves, is orthogonal to the wave front, meaning that the tangent of PB is parallel to the incident wave ray.

$$\int_{0}^{x_{B}} \left(\frac{dy}{dx} - \left(-c_{d} \tan\left(\frac{\pi}{2} - \beta\right) \right) \right) dx = 0.$$

$$a_{1}x_{B} + a_{2}x_{B}^{2} + a_{3}x_{B}^{3} = -c_{d}x_{B} \tan\left(\frac{\pi}{2} - \beta\right) \qquad \dots (9)$$

 c_d is the diffraction coefficient, with a range of $0.1 < c_d < 1.0$. Value c_d is obtained through calibration, by fitting the resulting stable coastline to the empirical shape of a crenulate bay.

4. At the terminal point of the stable coastline, where $x = L_{inf}$, y = 0, the coastline returns to its original position. $a_0 + a_1 L_{inf} + a_2 L_{inf}^2 + a_3 L_{inf}^3 = 0$... (10)

There are four linear equations with four unknowns, namely equations (7), (8), (9), and (10). Using these four equations,

the polynomial coefficients a_0, a_1, a_2 dan a_3 , while L_{inf} is obtained through trial and error, until a condition is found that corresponds to the characteristics of a crenulate-shaped bay.

3.1.1. Crenulate Shape Bay Equation

There is a stable coastline between two headlands (Fig(4)) in the form of crenulate.



Fig.4: Crenulate shaped bay

Crenulate shaped bay equation proposed by Hsu & Evans (1989),

$$\begin{aligned} \frac{R_{\theta}}{R_{0}} &= C_{0} + C_{1} \left(\frac{\beta}{\theta}\right) + C_{2} \left(\frac{\beta}{\theta}\right)^{2} & \dots (11) \\ C_{0} &= 0.000000479 \ \beta^{4} - 0.0000087963 \beta^{3} \\ &+ 0.0003521878 \ \beta^{2} + 0.0047891887 \beta \\ &+ 0.0715244255 \\ C_{1} &= -0.0000001281625 \ \beta^{4} + 0.0000181988465 \beta^{3} \\ &- 0.0004865839195 \beta^{2} \\ &+ 0.0077130700611 \beta \\ &+ 0.9551247533875 \\ C_{2} &= 0.00000011262 \ \beta^{4} - 0.00001561035 \beta^{3} \\ &+ 0.00055939061 \beta^{2} \\ &+ 0.01497707408 \beta + 0.0859531142 \end{aligned}$$

Seen from the definitions of R_0 , R_θ , β and θ , both β and θ are expressed in radians. Using the relevant equation, the value of y_{min-c} , which represents the lowest point of the crenulate-shaped bay, can be determined.

In the stable coastline model, two critical parameters must be evaluated: the diffraction coefficient c_d (see Equation 9) and the length of the stable coastline L_{inf} (see Equation 10). Both c_d and L_{inf} are unknown variables and must be determined

through a trial-and-error procedure. Further calculations are conducted in the segment exhibiting a crenulate-shaped bay geometry (as shown in Fig (5 and 6). Within this region, R_0 is computed, and subsequently, y_{min-c} is determined using (11). The model's accuracy is verified by comparing the computed minimum value y_{min} with y_{min-c} .

As an illustrative example, the model is applied to a coastline featuring a single groin with a length of $L_g = 100 m$ and an incoming wave angle of 15^0 . Through the trial-and-error procedure, the values $c_d = 0.35$ and $L_{inf} = 75 m$ meters are obtained (see Fig.(5)).

There is a crenulate shape bay profile on the stable coastline, with the headland presented in Fig (6).

The headland is situated at an elevation +1.590 *m*, with a distance between headlands $R_0 = 56.874$. The minimum point relative to the headland axis is $y_{min} = -13.646 m$. Using (11), $y_{min-c} = -13.192 m$ is obtained with relative difference $\varepsilon_R = \left|\frac{-13.646+13.192}{-13.192}\right| x100\% = 3.44\%$. This difference can be further minimized by adjusting the value of $L_{inf} = 73.0 m$, to obtain $\varepsilon_R = 0.01\%$.



Fig.5: Stable coastline profile

From the review of stable coastline tangents, it is observed that the average tangent of line AB is $-\tan\left(\frac{\pi}{2} - \beta\right)$, perpendicular to the diffraction wave. Meanwhile, the tangent of line BC is $\tan \beta$, both of which meets the condition for a stable coastline being perpendicular to the wave direction that governs sediment transport. These findings confirm that the requirement for a stable coastline tangent to be perpendicular to the wave ray or parallel to the wave front does not imply that the resulting stable coastline must be a straight line. Rather, the stable coastline may take a curved or nonlinear form, as long as the local tangents align with the direction of the sediment-transporting wave.



Fig.6: Headland analysis



2.2. Model stable coastline on the upstream groin

The development of the stable coastline model on the upstream side of a groin is based on the assumption that there is an adequate supply of sediment from the updrift. Under this condition, over a sufficiently long time period, sedimentation will accumulate until it reaches the tip of the groin, as illustrated in Figure 7. In the event of sand bypassing, the stable coastline profile remains unaffected and continues to follow the same configuration as depicted in the figure. Accordingly, the first characteristic of a stable coastline is that at point A, where $x = L_{inf}$, $y_A = L_a$.

the second characteristic of the stable coastline is observed at point O, where x = 0, y = 0 and $\frac{dy}{dx} = 0$. The third characteristic is that the average slope of the stable coastline corresponds to $\tan \beta$. Therefore, the length of the groin's influence, or the extent of the stable coastline that forms, is expressed as:

$$L_{inf} = \frac{L_g}{\tan\beta} \qquad \dots (12)$$

There are three characteristics of the stable that can be approximated by a quadratic polynomial with three unknown coefficients, represented as:

$$y = a_0 + a_1 x + a_2 x^2 \qquad \dots (13)$$

To determine the coefficients of this polynomial, the following boundary conditions are applied,

- 1. At point x = 0, y = 0, hence $a_0 = 0$... (14) 2. At point x = 0, $\frac{dy}{dx} = 0$, $a_1 = 0$
- 3. Furthermore, the average slope of the curve from point OB is $\tan \beta$,

$$\int_0^{L_{inf}} \left(\frac{dy}{dx} - \tan\beta\right) dx = 0.0$$

$$a_{2}L_{inf}^{2} = L_{inf} \tan \beta$$

Substituting (12),
$$a_{2} = \frac{\tan^{2} \beta}{L_{g}} \qquad \dots (15)$$

Accordingly, the stable coastline equation at the upstream groin can be expressed as:

$$y = \frac{\tan^2 \beta}{L_g} x^2 \qquad \dots (16)$$

As an illustrative example, consider a groin with a length of $L_g = 50.0 m$, incoming wave angel 15^0 . Based on (12), the groin's influence area is calculated as $L_{inf} = 186.60 m$, with stable coastline profile presented in Fig (8).



Fig.8: Stable coastline on the upstream groin.

As shown in Fig (8), the derived profile satisfies the conditions for a stable coastline, particularly the requirement that the average slope of the coastline corresponds to $\tan \beta$.

IV. STABLE COASTLINE BETWEEN TWO GROINS

On developing a stable coastline model between two groins, an important assumption is made: the distance between the groins is sufficiently short such that interaction occurs between them. The criterion for a "short" distance refers to the condition in which sediment deposition does not extend beyond the length of the groin. This distance is relative and largely influenced by the groin length itself the longer the groin, the greater the allowable spacing between groins while still being accommodated.



Fig.9: Stable coastline between two groins.

The stable coastline between two groins is approximated using a second-degree polynomial function:

$$y(x) = a_0 + a_1 x + a_2 x^2 \qquad \dots (17)$$

To determine the values of the three unknown coefficients, three equations are required. These are obtained from a mass conservation principle and two boundary or characteristic conditions.

$$\int_{0}^{L} y \, dx = 0$$

$$a_{0}L + \frac{1}{2}a_{1}L^{2} + \frac{1}{3}a_{2}L^{3} = 0 \qquad \dots (18)$$

In this context, it is assumed that the eroded and deposited sediments possess the same porosity coefficient and are both in a saturated state.

2.At x = 0, a boundary condition analogous to that used for the downstream side of a single groin (as previously described in (4) and depicted in Fig. (3) is applied,

$$a_o = c_s x_A \tan\left(\frac{\pi}{2} - \beta\right) \qquad \dots (19)$$

Where $x_A = L_g \tan \beta$.

 c_s is a coefficient dependent on both the groin length L_g and the spacing between groins L, For a given pair

of values (L_g, L) , c_s is treated as a constant for a specified wave angle β .

3. The third condition asserts that the average tangent of the stable coastline between $x = x_A$ and x = L is tan β ,

$$\int_{x_A}^{L} \left(\frac{dy}{dx} - \tan\beta\right) dx = 0$$

$$a_1(L - x_A) + a_2(L^2 - x_A^2)$$

$$= (L - x_A) \tan\beta \qquad \dots (20)$$

By simultaneously solving Equations (18), (19), and (20), the coefficients a_0, a_1 dan a_2 of the polynomial can be determined.

As an example, consider a model using a groin of length $L_g = 30 m$, wave angel 10^0 and L = 50 m. The resulting stable coastline profile is shown in Fig. (10). In this case, a value of $c_s = 0.153$, where $y_{min} = -3.538 m$. Since the groin spacing is known, the only parameter adjusted through a trial-and-error process is the coefficient c_s .



Fig.10: Stable coastline profile between two groins.



Fig.11: Verification of model results for a crenulate-shaped bay

The headland of the bay is situated at an elevation of y = 4.590 m, with the left headland positioned at the groin location x = 0 (Fig (11)). The right headland is located at x = 44.533 m, therefore $R_0 = 44.533 m$. Using Equation (11), the minimum elevation of the crenulate-shaped bay is calculated as: $y_{min-c} = -8.137 m$, yielding $(y_{min} - 4.590) = -3.538 - 4.590 = -8.128 m$. Relative gap: $\varepsilon_R = \frac{-8.137 - (-8.128)}{-8.137} x \, 100\% = 0.110 \%$.

The slope of line AB is $-\tan\left(\frac{\pi}{2} - \beta\right)$ perpendicular to the diffracted wave direction Conversely, the slope of line BC is $\tan \beta$, parallel to the wave front.

V. CONCLUSIONS

Based on the analysis of the stable coastline's tangent, the polynomial approach adopted in this research yields a model that meets the criteria for a stable coastline. When evaluated against the established theory of stable coastlines in crenulate-shaped bays, the polynomial model also produces results consistent with observed patterns. Therefore, in general, the polynomial model developed in this research effectively represents the stable coastline configuration around a groin.

The coastal response to the presence of a groin involves both erosion and sedimentation processes. In eroded regions, the resulting stable coastline tends to form a crenulate-shaped bay. However, the interplay of erosion and sedimentation may also produce a crenulate geometry, as observed in the equilibrium shoreline between two groins. In the case of a single groin, erosion and sedimentation can occur on either the downstream or upstream side, allowing such structures to serve as effective protective measures against coastal erosion in their immediate vicinity.

In the design of groin systems for shoreline protection, the spacing between groins emerges as a critical parameter. Larger distances between groins tend to result in increased erosion, which may pose a threat to onshore infrastructure. Therefore, careful consideration must be given to the spacing in order to achieve optimal coastal stability.

In conclusion, while the principle of a stable coastline states that the tangent to the shoreline at equilibrium is parallel to the wave angle, this does not imply that the stable coastline is a straight line. Rather, the coastline may assume a curved form when the resultant tangent at any given point aligns with the tangent of the wave angle.

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Energy recovery and Analysis of performance criteria of the energy potential of biomass for the production of electricity

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Keywords— Biogas, biomass, electricity, methanisation, Gaussian Mixture Model (GMM), DEEPLEARNING. Abstract—This study focuses on the field of energy. Electricity production is an industrial sector that supplies consumers with electrical energy adapted to their needs. With current ecological and environmental requirements in the world, which wants to be more and more sustainable and non-polluting. The electricity production sector is seeking to exploit new sources of clean energy to align with today's sustainable context. The SDG 1. 7 for example is a leitmotif of the neo-producer of electricity in the 21st century who wants to guarantee access to reliable, sustainable and modern energy services for all at an affordable cost. So we made the choice of biomass in this work, as a source of primary, unlimited, non-polluting energy to produce, following its biochemical decomposition and fermentation, biogas which will be the raw material which will help us in the production of a electricity at a good price and accessible to large masses of the world population, two methods of analyzing energy performance criteria are developed in this work for a good selection of biomass, namely Gaussian Mixture Model (GMM) and DEEPLEARNING.

¹ The Sustainable Development Goals give us the way forward to achieve a better and more sustainable future for all by 2030. Objectives set by the United Nations to which all countries adhere.

I. INTRODUCTION

All organic matter, whether of animal or plant origin, can be methanized to be transformed into biogas . At present, we most often use: agricultural waste (animal waste, crop residues such as straw, etc.), green waste (grass clippings, etc.), waste from the food industry (slaughterhouses, vineyards, dairies, etc.), station sludge. The biogas can be used for cooking energy, cogeneration for heat production or to produce electricity. Electricity is more interesting these days because we are in the phase of eliminating fossil sources and renewable and new energies such as biomass to electricity are more and more in vogue. Hence the role of the scientists that we are to provide more information on its real valuation in electricity by providing reference values to have a good yield in biogas and therefore a quantity of electricity produced on a permanent basis.

1.1. WHAT IS BIOGAS ?

Biogas is the gas produced by the fermentation of organic matter in the absence of oxygen. It is a combustible gas composed mainly of methane and carbon dioxide. The procedure for obtaining this organic gas without greenhouse effect is called "methanization".

1.2. What is Methanization ?

It is anaerobic fermentation, which is one of the processes that contributes to the degradation of dead organic matter, vegetable or animal, and their transformation into simple, gaseous and mineral elements. Thus the biological cycles are maintained where "nothing is lost, nothing is created, everything is transformed" [1].

Anaerobic digestion takes place in the absence of oxygen, which stabilizes organic matter by transforming it as completely as possible into gas (methane CH4 (50 to 75%) and carbon dioxide CO2 (25 to 50%)) [2]. It should be noted that it is microbial communities that are responsible for the decomposition of organic matter. The decomposition takes place in a closed container called a "digester".

Anaerobic digestion ultimately results in two categories of the following elements: biogas and digestate.

Biogas is a mixture of methane (CH4), carbon dioxide (CO2) and water vapor (H2O). Methane is the main constituent of natural gas. The digestate is the liquid residue containing the non-degraded materials.

II. PRODUCTION OF BIOGAS BY METHANATION ON THE DE BINZA-METEO SITE IN KINSHASA

In order to be able to identify the quantity necessary to be able to operate a generator and produce electricity thanks to the biogas collected, experimental studies have been carried out to have the quantities required for good exploitation of biomass in the production of electricity.

The experimental device consists of the following devices as shown in Figure 1. Below : A 3.5 m3 digester, a desiccant filter, a desulphurization filter, a gas meter, a 5 m3 PVC tarpaulin container and a generator 1.5 KW biogas.

It should be noted that concentrated products of the fermentation bacteria were added in the process in order to collect more of the biogas needed to operate a biogas generator.

Description and role of experimental equipment:

The digester: it is also called a biogas reactor, its role in this anaerobic tank is to digest the various organic materials placed there. To have a good yield, it will be necessary to add water to the digester, the quantities of which are given below in table 1.

filter : is a filtration system which aims to separate water from gaseous particles (biogas) from water (H2O) by passing the product leaving the digester through a porous medium.

Desulfurization filter: safe elimination of hydrogen sulphide contained in biogas[3];

Storage container: waterproof PVC envelope intended to preserve the biogas produced;

generator : produces electricity with biogas used as fuel.



Fig.1: Experimental device (Named: MATITI ENERGY, Matiti which means plant or leaf in Lingala, vernacular language spoken in Kinshasa in DR Congo, 2020).

III. ANALYSIS METHODS

3.1 Gaussian Mixture Model (GMM)

In machine learning, there are two areas which are supervised learning and unsupervised learning.

The difference between the two is the approach used to

solve the problem statement and the data used in the approach [4].

There is a term in unsupervised learning called clustering in which we find the groupings of data points with certain common characteristics.

Now clustering means finding the set of points which are close to each other compared to other data points.

In our diagram below, we clearly see two sets of clusters or set of data points that are close to each other :



Fig.2: Data points

You can see it in the image below where the two sets are shown in blue and red.



Fig. 3: Groups Gaussian Mixture Model

Gaussian Mixture Model is a function that includes several Gaussians equal to the total number of clusters formed. Each Gaussian in the mixture carries certain parameters which are:

- 1. An average, which defines the center.
- 2. A covariance, which defines the width.
- 3. A probability.



Fig.4: Gaussian Mixture Model 'GMM) clusters

Here you can see that there are three clusters which mean three Gaussian functions. Each Gaussian explains the data present in each of the available clusters.

Since there are three (k = 3) clusters and the probability density is defined as a linear function of the densities of all these k distributions.

$$p(X) = \sum_{k=1}^{K} \pi k G(X | \mu k, \Sigma k)$$
(1)

Where πk is the mixing coefficient of the k distribution

This enables applications such as object recognition, background suppression and medical image analysis.

Image segmentation: GMM is widely used in image segmentation tasks. By modeling image pixels as a mixture of Gaussian components, GMM can effectively distinguish different regions or objects in an image [5].

The Gaussian mixture model finds applications in various fields, thanks to its versatility and ability to capture complex data patterns.

A Gaussian mixture model is a versatile probabilistic model capable of capturing complex data distributions by representing it as a combination of multiple Gaussian (normal) distributions.

3.2 Deep Learning

Deep Learning is based on a network of artificial neurons imitating the human brain. This structure is arranged in several layers, interconnected with each other.



Fig.5: Neural structure

The first layer corresponds to the input neurons and the last one transmits the output results. Between the two are several intermediate layers through which information is

V

processed. This architecture is specific to deep learning and allows each layer to more accurately analyze the input data.

Thus, the deeper the artificial neural network is and therefore contains several layers, the more the system can perform complex tasks. It is able to determine by itself a representation of what it receives, whether it is an image or a text.

With each piece of information integrated, the connections between neurons expand and change. This is why a system with deep learning AI has the ability to learn new things on its own. It also improves its forecasting and decision-making on its own, with no human intervention required. It therefore has the particularity of learning from its own mistakes [6].

Deep learning is therefore comparable to a network with several levels of information distillation operation, where the information passes through successive filters and emerges more and more purified (i.e. say useful for certain tasks).

IV. CALCULATION OF THE VOLUME OF A BIOGAS DIGESTER

The type of digester used in this document, a removable digester, is made of metal and plastic materials and all assembled.

3.3 . How to calculate the volume of a digester? [7]

The size of a micro biogas plant or a digester to carry out methanization (using organic matter such as : animal defection, agricultural waste, etc.)

In general the calculation of the volume of a digester filled with organic waste depends on fundamental assumptions in relation to the daily supply and the water level in the digester.

The digester level can be calculated by the following relationships:

$$VD=Vsg+Vd$$
 (2)

VD= Total volume of the digester;

Vsg: Gas storage volume;

Vd: Digester volume;

$$/d = T*Vdm$$
 (3)

T: Retention time of waste in the digester which is between 30 and 50 days;

Vdm: Quantity of organic waste mixed with the water fed daily into the container;

$$Vdm = W + nL \tag{4}$$

W: Quantity of water used to mix with organic waste;

$$sg = h*S$$
(5)

h: height of the gas storage from below the ceiling of the digester to the slurry level inside the digester in (m) is generally 0.4m hence:

$$Vsg = 0.4 * S \tag{6}$$

$$VD = (0.4 *S) + nLT$$
 (7)

The volume of biogas being in KWh, it should be noted that each m3 of biogas can produce 6KWh. [8]

V. RESULTS AND DISCUSSIONS

The objective of this work is to identify the exploitation values of the biomass capable of providing the biogas necessary to power an electric generator. After applying the relationships above we were able to find the range values applicable to digesters, allowing us to have a quantity of biogas necessary to generate electricity. We have a table below, associating the size of the generator, with the capacity of the digester and subsequently identifying the capacity of the types of biomass elements admissible in the digester and the quantity of biogas extracted.

Table.1: Reference table digester size and generator capacity

Digester size(m3)	3.5(m3)	15	2 units of 15 m3	66 m3	2 units of 66 m3
Water level (m)	1.1m	1.25 m	1.25m for each container	1.8m	1.8 m for each contai ner
Capacité(m3)	1.7 m3	8.8 m3	8.8 * 2	12.7	12.7 * 2
Biogas storage capacity (m3)	1	4.9	4.9 * 2	25	25*2
Digester size	1.95 W * 1.65 H *0.98 W	3D *2.5 H	(3D*2.5 H)*2	(6D* 3H)	(6D* 3H) *2
Occupied floor space (m3)	1.87	7.1	7.1*2	29	29*2
Generator capacity to operate kW	1.5KW	5K W	10KW	20K W	50K W

In order to have a good yield of biogas from the digester

and have a good Vdm, there are proportions which allow us to have a good yield which we summarize in the table below.

Table.2: Constitution of waste in the digester
per Kg/day

MATTER In Kg/day	Digester 3.5 m ³	Digester 3.5 m ³	Digester 3.5 m ³
Rest of human food	25	125. 0	475
Pig defection	45	225	855
Cow defection	60	300	1140
Hen defection	26	130	494
Human defection	32	160	608
Restoffruitandvegetables	65	325	1235

The two tables show us sufficiently how much waste we can have in well-sized containers that can power biogas generators and provide reliable and permanent electricity thanks to our own waste. There is also an indicator table to achieve optimal performance in terms of biogas recovery according to the nature of the organic waste in our possession.

3.4 Gaussian Mixture Model (GMM)



Fig.6: Classification and superposition of flames.

4.2. Deep Laerning

At this level, we have resized all the images to the same size to train the model and validate it.

There is a distribution key for training and validation data:

We have 70% of the data to train, 15% of the data to test, and 15% of the data to test.

The figure below (7) presents the trained data and those validated according to the data distribution key described above.



Fig.7: Test and validation data

Figure 8 below presents the complete architectural network of the model to be trained.

This network is subdivided into two layers the Hidden layer and the Output layer.

The first layer, the Hidden Layer, presents the number of neurons to train, which is 14.

The Hidden Layer is a hidden layer between the input and the output of the algorithm where the function applies weights to the inputs and directs them to the output through an activation function. This layer performs nonlinear transformations of the inputs introduced into the network.

The Output layer is the output layer, or final layer of the neural network, where the desired predictions are obtained.

The Output Layer, presents the number of predictions desired on the recorded data and which is 324 predictions.



Fig.8: Architectural network of data to train

Analytical prediction relies heavily on machine learning using historical data, statistical algorithms and machine learning approaches.

Predictive analytics is able to determine the probability of events futures in order to extract information from large databases and predict future events. The figure below shows the results of a combustion model in relation to the data obtained from the combustion chamber (Figure 3.1.). We note that the degree of precision on the prediction is not conclusive in comparison with the data obtained during the classification phase (see Figure 6).



Fig.9: Prediction on model data

The extraction of classification metrics to evaluate the performance of Machine Learning and Deep Learning models is based on the essential foundation which is the Confusion Matrix. Mastering it is therefore an essential prerequisite for fully understanding the performance of a classification model. This matrix is essential to define the different classification metrics such as: Accuracy, ROC (Receiver Operating Curve), F1-Score or even AUC PR.



Fig.10: Confusion matrix

The ROC or ROC (Receiver Operating Characteristic) curve is a graph that illustrates the diagnostic capacity of a binary classification system based on the variation in its threshold for discriminating two classes. It can also be called the curve illustrating the performance characteristics of the receiver .

The ROC curve is the plot of the true positive rate (TPR) against the false positive rate (FPR), at different thresholds. This curve indicates the sensitivity as a function of the specificity of the metric.

The figures below (Figure 11) represent the rate of true positives and false positives for our starting data (Figures 6).

By comparing the results from the three separate data sets , we see that the nature of biomass influences the degree of precision in the prediction. Thus, as we can see in the figures below relating to the initial data, that the blue curve relating to cow dung. Gives more precision of true positives while the other two, more precision of false positives.



Fig.11: Receiver Operating Curve (ROC)

The analysis of the concentration of the detonation is carried out in this work to validate or confirm the different predictions made above. Thus we can see in the figures below that the concentration is strongly defined in figures 13 and 14 this is to confirm that the more strongly the biomass is loaded, the greater the precision of the reading.



Fig.12:Concentration density



Fig.13: Concentration density



Fig.14: Concentration density

VI. CONCLUSION

The first goal of this work is to show how we can go from biomass via methanization to obtain biogas and subsequently quantify the energy value (electric) in terms of KW but also to carry out an analysis of performance criteria of the energy potential of three types of biomass namely, the rest of human food, pig defection, cow defection.

Something that has been successfully brought out in this article. This demonstrates that a digester mounted on the surface with a well-sized volume, respecting the waste conditioning timing, could give a constant quantity in time t and capable of producing permanent electricity. Table 1 gives an illustrative drawing of the results starting from 1.5 to 50 KW of electricity capacity to be produced with an associated size digester ranging from 3.5 m3 to 66 m3.

The analysis also led us to a conclusion which is that a judicious choice of the biomass leads to good results, such as the observation above that the defection of cows has a great energy potential compared to the other types of biomass under examination.

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