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Cutting-Edge Applications of AI in Deep Learning: Recent Research

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Abstract:

As it is seen, construction business operates with time and money overruns, productivity constraints and labor shortage as its prevalent issues. They found that in every phase of a project, it is severely lacking behind in terms of digitization as compared to most of the industries. When it comes to innovation in building, the emergence of machine learning (ML) and artificial intelligence (AI) has revolutionized the industry. While all these technologies are useful in architecture and construction, a systematic analysis of their utility across the several stages of a building project life cycle is still missing. Towards this research gap, this study will explore the usage of AI & ML across different phases of construction projects, with the ultimate goal of availing relevant info for incorporating these intelligent solutions into practice. The rationale for this literature study was to identify potential indoor environment related uses of AI and ML. This was followed by the literature review where a building project life cycle was used to demonstrate the possible uses of AI and ML. To undertake the literature analysis of the adoption of AI and ML the construction sect or, it was identified that the most common usage of such technologies lies in the planning and construction phases of a project. Moreover, this study offered and examined the potential of AI and ML for the next stages according to the life cycle categorization in addition to identifying pertinent patterns. The real strength of the study therefore lies in the insights that can be derived from examining a relatively mature and traditional branch of the construction industries revealing how the industry sectors might start to harness intelligent technology in more effective ways. The scholarship contribution of this research includes conducting a literature review, performing an analysis of their applications based on the life cycle of building project, and identifying possible opportunities for the deployment of AI and ML at different stages of a project

Keywords **— Construction, Digitization, Artificial Intelligence (AI), Machine Learning (ML), Building Project Life Cycle, Technology Adoption,**

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I. INTRODUCTION

Efficiency enhancement drives the construction industry to address the contemporary and future requirements. According to the latest United Nations estimates, the size of the global population will go up significantly in the years to come. According to the projections, it will grow up to be 8. The cost is expected to be $ 4 billion in the year 2030 and 9. 6 billion in 2050. Globally, people can potentially be a possible 10. It was forecasted to reach 4 billion during the year 2100 [1]. The current construction industry is however unable to provide infrastructure at the desired pace as the upcoming demand for such facilities forecasted in the near future overwhelms the capacity and capability of the current construction industry. As a result of the sector's ineffective adoption of digitization and

heavy dependence on manual processes in contrast to other sectors, the construction sector is currently unable to meet the expected infrastructure requirements in the near future. Some of the causes of misfortunes in the construction industry include low technology literacy as well as low levels of technology application. Due to these issues, projects have been completed late, produced low quality, made wrong decisions, underachieved, and have witnessed low health and safety performances [3].

Lately, the construction companies are exploring AI (Artificial Intelligence) and are possibly implementing it to enhance the productivity and outcome in spite of the slow pace of growth of the construction industry. Several advantages may be accrued from this attempt; these include; Cutting down on costs of construction through decreasing cost overruns Enhancing site safety; Enhancing productivity at the sites; Enhancing efficiency in the planning and coordination of projects [4]. Because of the AI technology, these businesses now have an edge over others in the current market through the automation of certain operations. Based on an analysis of the literature it is clear that the application of real digital tools and techniques in engineering, construction and management is greatly aided by AI technologies. The field of artificial intelligence (AI) is part of computer science where computers simulate the learning and information processing abilities of the human mind. Some of these talents include being able to display information, being able to visualize things, being able to solve problems, being able to think and being able to come up with certain plans. There is nothing new in the first three focuses as the use of artificial intelligence (AI) means that computers can deliberately, intelligently and adaptively solve all and any complicated and ambiguous situation. Machine learning, on the other hand, deals with "the ability to give a computer new skills, by feeding it raw data and creating a model which in turn can be controlled or used to generate further predictions through the avaible statistical methods" [5].

Many earlier authors have devoted their articles and papers to the regarding of artificial intelligence and its branches as they relate to the construction industry and the issues affecting it. For instance, machine learning has proved helpful in the construction field where its application can be found in cost, health, and safety concerns, risk factors, optimization of logistic, and supply chains. Robotic technologies play numerous roles in construction and civil engineering, from offsite construction, site monitoring, productivity evaluation, and material movement, and equipment navigation. While there is an abundance of information about AI and ML as futuristic tools, there is little literature out there explaining the part they play in construction. To address this issue, this research looks into the existing literature on the basis of which the author examines the principles and the current state of AI and ML in connection with the construction industry. This paper was inspired by the scarcity of such a literature review that sought to draw a comparative analysis between the two models. It is important to note that, despite the unprecedented potential that AI and ML offer in the constructions industry, the applications are not yet properly benchmarked concerning the multiple phases of a construction project. Therefore, the following research question is proposed and aims to identify the state-of-the-art and principles of artificial intelligence and machine learning with focus on the building industry: This report assesses the application of structured problem-solving methods throughout the stages of the projects involved.The purpose of this study is to have a comprehensive understanding of the use of AI and ML in every phase of construction projects' life cycles. It is hoped that these insights could facilitate the efficient, cost effective and effective integration of the smart systems in construction industry. Specifically, three main resolutions were made in a bid to achieve the goal deemed important before the discussion of this paper.

- Identifying the history, concept and the technicalities of the uses of AI & ML.
- As shown in the previous chapter and supported by research evidence, the use of artificial intelligence or machine learning in construction was reasonably active between 2010 and 2022.

• Discussion of how the project application of AI and ML takes place at some time in the cyclic existence of projects.

II. METHODOLOGY

A three-part comprehensive review process that involved fading out a vast number of articles that suited the objectives of this research was used. As part of the process of seeking information, specific databases are first scanned for material relevant to the topic of interest, after which material not relevant to the topic is culled out, and what is left then evaluated. The survey was conducted using a three-step strategy as outlined below in the Figure 1 below.

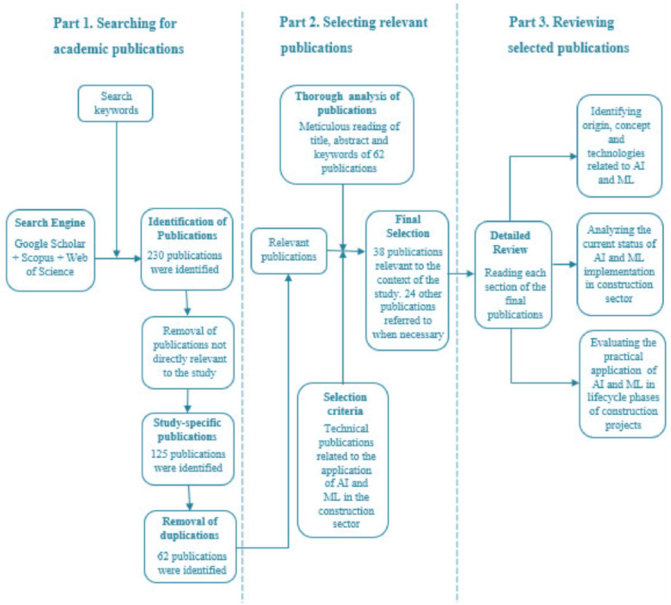

Fig 1: The major analytical technique employed in this study was PRISMA, which was conducted following the PRISMA flow diagram

2.1 Looking for scholarly journals

first, Google Scholar, Science Direct, Scopus, and Web of Science were used to conduct the search for the literature related to the topic. These databases offer a wide range of coverage of scientific journals and other research articles [6]. The writers carried out detailed searches using both the article title/abstract/keyword format in the aforementioned search engines. The first part includ ed the keywords like " artificial intelligence", " machine learning", " automated planning / scheduling", " natural language processing" and " computer vision". In the second part the search phrases were like " construction", " construction industry", " construction engineering", " construction management" and " construction engineering and management". Hence, to ensure a comprehensive analysis given that the use of artificial intelligence and machine learning applications is yet to fully mature in the construction industry, this study was limited to publications between 2010 and 2022. However, in an attempt not to narrow down the search in a way that publications would be limited to specific journals , study was not limited to any journal. Based on this classification, "Article" or "review" was chosen as the document type because sources of this type are the most authoritative and recognizable [7]. The first procedure of the research was a search on Google Scholar with articles in the field found to be 121. For our search we used the databases PubMed and Google Scholar which provided 204 papers and to ensure a more extensive source we used Scopus and Web of Science and the total papers found were 230. Then a search was conducted in the databases for 125 journal articles and conference papers which were not relevant to the research and were eliminated from the collection of sources, and the collection of sources was final. To ensure all publications focused on the construction industry, each item on the list was evaluated by the authors; any that were not considered to be relevant to the construction industry were excluded from the list. It is possible to find three or more papers from this level of the study in well-established journals such as; Automation in Construction, Journal of Construction Engineering and Management, Engineering Applications of Artificial Intelligence, International Journal of Construction Management, Journal of Building Engineering, and Advanced Engineering Informatics. They have been derived out of 33 different scholarly journal articles and conference papers, to date the set totals 62.

2.2 Choosing appropriate journals

Therefore Part 2 is directly related to the first in that it outlines the detailed findings having looked at the 62 papers of consideration. Now, its time to find out, which of the publications can be deemed to be more relevant to our study. In order to identify

the relevant ones, we searched through 62 research publications aiming to scrutinize their titles, abstracts, and keywords. Therefore, in this review, we identified and selected 38 publications that we felt addressed or related to the concept. Some publications were excluded to make sure that only articles that dealt with their subject matter in matter in phases of the building project lifecycle applied Ai & ML were included. Particularly, there was an expectation of papers that presented new angles to look at some aspects of the traditional construction process. Also, the writers cut papers that express similar usage to eliminate redundancy and ensure only unique examples are used. Here, the most recent one is to select the one which best fits the third criterion, utility, cost, and overhead. When considering the selected articles In order to explore the history, conceptualization, and advancement of AI and ML, the content analysis in this regards was conducted throughout this stage. From the articles selected for this study, we also had several research questions such as the following: How far down the AI & ML Adoption curve is the construction sector?; How and at which stages of the construction process are AI & ML being used in the real world? The term connection diagram of the Articles on in action AI and ML are captured in figure 2 below. These 36 key terms were classified into four clusters using a cluster hierarchy that determines the interrelations between the keywords, and which is illustrated in Figure 2. The following words and phrases have been determined to be of importance in these research works and they carry a total link strength of 1232, namely, “Machine learning,” “AI technology,” and “Construction industry.

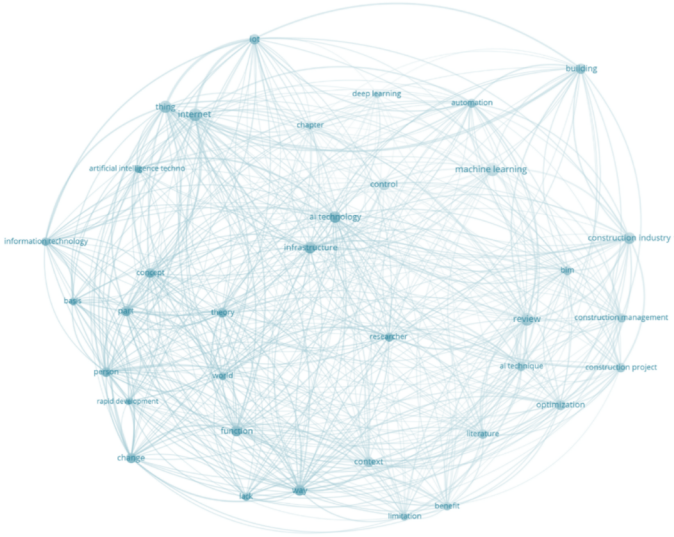

Fig. 2: The diagram below illustrates relating the keyword used in the completed literature review

”This work has established that Internet, building, infrastructure, and review are synonyms. All of them, the add-up of the connection strength sum up to be equal to 610. Additionally, the historical developments, definition, fundamental ideas, and key instruments of AI and ML pertaining to implementation are presented. However, the current adoption and implementation of AI or ML in the construction sector are the focus here. In such section, or section 5, other uses of AI and ML within the whole cycle of construction projects will be discussed.

2.3 History, principles and development of artificial intelligence and machine learning

Information technology, artificial intelligence, and applied maths are intertwined in the modern sectors of artificial intelligence and machine learning [8]. Computing defined artificial intelligence (AI) as the field that deals with the development of intelligent computer programs that can reason, learn, and act like human beings [13]. Machine learning as an approach of artificial intelligence comprise to the development of the models and algorithms that will enable computer to learn from the data without any special human intervention, the aim of which is to enhance its performance [9]. The proposal of replacing real human intellect with machines has its beginnings in numerous fields such as philosophical writings, today’s modern science-fiction works, and even the

scientific fields of computer science, electronics and engineering fields of today [10]. Alan Turing proposed the intelligence test that was significant in the development of artificial intelligence as it shifted an outlook from traditional religious and mathematic appearances to what could be done with computers [11]. Depending on artificial intelligence, and 60 years from now, intelligent robots that replace the human have already exceeded the ability in many sectors, but particularly in learning.

This unbelievable concept is now possible due the fast growing in the advancement of various technologies like the Big Data Analysis and Increased computational power of the computers. Artificial intelligence can also be described as the science of how computer systems can perform tasks that are typically accomplished by people in the most effective ways. These are the three types of AI currently being put in place for categorization: "Artificial Narrow Intelligence (ANI)" "Artificial General Intelligence (AGI)" and "Artificial Super Intelligence (ASI)."These classes demonstrate the different levels of AI skills. The use of the various classifications of power described in the present book is viewed by the writer as advantageous. Specific subtypes are ANI or weak AI, which acts smart only some of the times for certain tasks. Identifying the right restaurant to eat, cars to drive, and clothes to wear, recommending a movie to watch, book to read, and organizing a meeting, and analysing a text, interpreting it in different languages and even predicting whether it will rain tomorrow, all are the applications AI with ANI. It is argued that while general intelligence marks the high level of the hyper-society, ANI, first of all, is oriented towards specialized knowledge. AGI or strong AI, proposes that machines are endowed with cognitive capabilities that are somewhat comparative to humans. The ultimate aim is to develop AI systems that are able to apply their thinking in several fields of interest as well as perform several jobs as that of humans. Knowledge, learning, seeing, acting, planning and communicating as the key facets of artificial intelligence. As AI has extended its applications to different industries, subfields of AI have been developed such as, Optimization, Knowledge-based systems, Computer Vision, Natural Language Processing, Automated Planning and Scheduling, Robotics and Machine learning. Machine learning applies the concepts of implementing a computer program that can enhance its abilities using statistical and computational methodologies to learn from previous experiences.

The end-purpose is to develop model that can be trained in performing a task, in predicting or even self-organizing autonomously. Machine Learning is a field that encompasses various subcategories, thus, Supervised Machine Learning is one of them. This area examines how computers can make decisions by state labelled in pairs of inputs and outputs. There are two primary subfields within machine learning: The process of building a model involves two major forms of supervised learning: the classification and regression. Regression prediction deals with the future numerical value while classes try to sort data in a predetermined manner; A subfield of the ML is "Unsupervised Machine Learning" which deals with the process of training a computer to learn the pattern from the data that is not labelled. Methods like dimension reduction, which simplifies the data, and clustering, which puts together comparable data points, are part of it; RL: The primary goal of reinforcement learning is to learn how to implement a function so that the magnitude of a reinforcement signal or a reward can be optimized for any given condition in an environment as well as the operational link between such conditions and feasible behaviours. A computational framework that learns from its surroundings via interactions is at the heart of the proposed method; and Deep Learning: This type of ML is regarded as one of the most advanced means to analyse the data and is known to provide more accurate determination of the target values as compared to less modern techniques. The rationale of this technique is to enable training of multi-layered deep neural networks to identify different and multiple layers of patterns in the data. Deep learning is a subfield of ANN where we have moved to the higher levels. The first wave of machine learning was generated by the invention of the overall back-propagation algorithm, which is the key of the total neural networks' concept.

III. STATUS OF AI AND ML APPLICATIONS IN THE CONSTRUCTION SECTOR

Advances in parameter efficiency allow computing greater velocity and enhanced sophistication through layered network integration. Today, CNNs are fundamental basic blocks that can be widely incorporated into various areas of machine learning, especially in computer vision tasks. These include object recognition, picture recognition, and so on and so forth, makes regular use of them. Collectively, for numerous tasks in computer vision, CNNs are a necessity since, due in part to their high performance, they are capable of accurately analysing input data to identify relevant information. Two potential fields that utilize Recurrent Neural Networks are natural language processing and voice recognition among other time series processing systems. There are many types of RNNs that have been developed, two of which include; Long Short Term Memory (LSTM) and Gated Recurrent Units (GRU). As partners, LSTM and GRU can store a value in a cell and, if needed, retrieve it — the same as an animal's memory. Advanced temporal architectures like LSTM and GRU are recently designed and popularized, which have been applied both in the research field and in the commercial area.

The numbers of articles published over the years in a specific area of study offer clues about its status and progress of a specific discipline. Illustrated in graphs 3 and 4 respectively they depict progress of AI & ML in construction sector. This is explicitly depicted by these figures of progress achieved in integrating these technologies into construction processes**.** This is because the artificial intelligence and the machine learning techniques were originally designed to be used in the manufacturing sector, but as time and utilization progressed they were also adopted by the construction sector and many more hence increasing the interest and research. This paper analysed this trend in the construction industry's research conducted over the last decade and found that machine learning receives more attention than even knowledge-based systems. As to the mentioned above occurrence, there is one possible explanation – the need to address existing shortages – both in labour and knowledge. Furthermore, among the major areas for pervading artificial intelligence in the construction industry is the Robots. This is especially the case given that newer technologies which seems to have been developed lately have proven useful in the construction industry such as; Exoskeleton systems. In particular, there is a vast number of computer vision-based technologies under the banner of BIM that are steadily infiltrating the construction industry. These technologies are designed for purposes such as; to manage and observe site safety, enhance job productivity, evaluate structure health, etc.

Some of the primary advantages of vision-based approaches over traditional approaches employing other type of sensors are as follows. Among them are the following: Invasive, friendly to the user, possibility to make measurement from remote distance and possibility to use it by everybody (you do not need any extra measuring or receiving instruments). Tentatively it can be expected that the construction industry is going to witness a rapid acceptance of computer vision oriented technologies primarily due to the wide spread availability of affordable and capable digital cameras in the construction industry. Some of the risk concerns are working at heights, handling of what may be considered as hazardous building materials – this is among the reason why the consideration of is especially important [36]. Being an effective method for health inspections, as well as the monitoring of buildings' activity, vision-based crack detection systems are gradually gaining reputation within the context of the construction industry. As is clear from the extent of its application for searching for fractures in concrete structures, this method has become quite popular. We highlighted the current concepts prevalent in the field of civil infrastructure assessment and the flaws detection using computer vision over asphalt and concrete structures. In this case, their research showed that image-based techniques could effectively be employed to provide automatic means of detecting and classifying fracture and spalling conditions in such structures. Picture and video data collecting has certainly advanced tremendously, but there are still significant barriers to complete automation. Using image analysis, a technique for identifying and categorizing concrete faults into four groups: Rebar exposure is a condition in which rebars become exposed to the external environment due to loss of concrete cover, spot is a small area of concrete judging by size, depth, and location. , spalling is detaching of the concrete surface due to its fracture while crack refers to a gap or opening in concrete. It is almost impossible to signify outer corruption of viral films in direct brightening, and yet their proposed procedure was notably efficient in a broad spectrum of luminosity. Regarding the comparison to other popular CNN-based algorithms, including YOLOv3 and SSD,

the presented algorithm's advantages were measured higher speed of inference and overall accuracy.

Image rectification methods also demonstrate the potential in accurately quantifying the number of building material to require and ensuring the safety of construction workers. With the help of such technology, not only the amount of building materials can be measured, indicating the efficiency of work but the safety of the workers can also be managed. The literature review of a number of studies indicated that there was a clear and unique emphasis on the study of accident prevention amongst many researchers. Their system was real-time and based on video surveillance acquired by cameras. The objective of this approach is to minimize the chances of an accident claim arising from construction crews and sundry machinery. Previously when we consider applying Machine Learning (ML) concern area is more precisely the safety management in construction sector has been administered by adjusted shallow learning algorithms. The first-generation approach toward performing worker identification at the construction site is the safety vest detection suggested by Seong and coworkers. The suggested method could detect workers wearing safety-colored garments using color pixels that are connected to the safety vests. Another ML study field that Ryu et al. conducted concerned the feasibility of utilizing a wrist-worn accelerometer in identifying the motions of workers on construction sites. The field of image processing itself has got revolutionized during the early to mid two thousand when deep learning or neural networks became the standard approach. Deep learning algorithms were developed relatively early; however, the momentum to integrate them with the construction industry faced considerable challenges. For instance, RNNs were first developed in the early 1980s yet it was surprising that it took roughly twenty six years before the RNN technology was employed in robotic excavator for a blind obstacle detection. To clarify, when we talk about CNNs, it is important to remember that CNNs were first developed in 1989, however, they have only gained a significant amount of popularity lately, specifically when used in identify construction site fall risks in 2012. It has only been recently that the construction industry began to both see the massive benefits of new deep-learning technologies and note that the time required to progress from the creation of an algorithm to implementation has been greatly reduced. A good example of this is YOLOv3. It was launched in 2018 and adopted in 2019 to construct an operational system that will diagnose tangible flaws in sewage pipes.

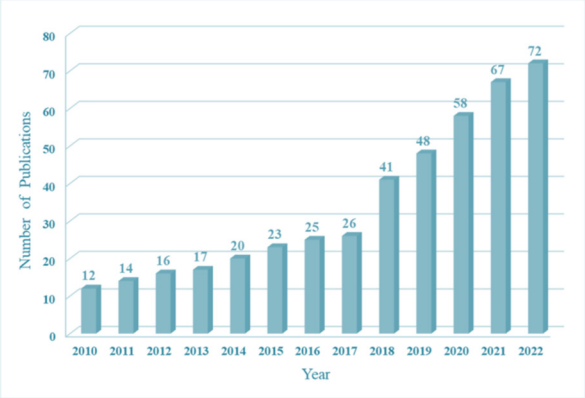

Fig 3: That represents the yearly trend in the construction industries in applying AI application.

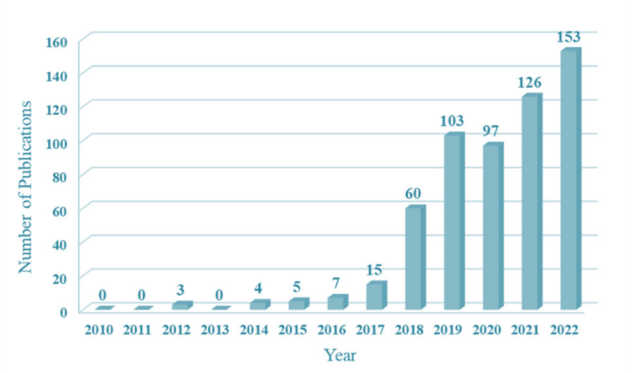

Fig 4: demonstrates the level of yearly ML application for construction sector, which constantly changing all year around.

IV. PRACTICAL IMPLICATIONS AND FUTURE RESEARCH

This research aims to establish the construction industry's level of advancing towards AI and ML implementation. In a concise manner, these technologies can be applied in physically constructing, operating and maintaining, demolishing and recovering the building. It may be helpful for the professionals and stakeholders in the construction sector involving numerous issues who are keen in using AI and ML solutions in this field to read the study. This would be more appropriate in ensuring that these intelligent technologies are integrated into the project at different phases ranging from construction to completion. Altogether, the findings of the present study hold

relevance beyond the academic arena; they are practical, as well. Thus, based on our findings, it will be possible to identify what subfields of AI and ML are the most relevant to the firms within the construction industry and therefore, of interest to the universities. It is possible for practioners to have some clue on potential future uses and broad implementation of technology in firms from the many application and technologies in AI that are being studied at the moment. As noted in the literature, the area receiving the most attention is the ML applications area thus implying that it may be the area that holds answers on how to direct future investment in order to enable the expected economic returns. Now that they know this, the construction managers can give these strategies a test inside their own organizations and invest the money into the research and development that will help bring these solutions to the sectors where they may be most useful.

Here in this study, the research that can study the lessons that practitioners can learn from AI technology, the research that describes previous techniques, and the most common issues that previous researchers faced is presented, and the research that provides general guidelines and provides information on general best practices is also presented. Due to the fact that there is so much empirical work on AI and it is spread out across such a wide span of disciplines within organizational settings, it can be quite daunting for many practitioners in the field to locate relevant empirical work. Since it is not simple to detect research that is bound to the problems that practitioners and their organizations face when implementing, extending AI applications, it is easier to synthesize results and present the studies thematically.

However, despite the amount of important contributions given in this study, there are some limitations that are worth to be noticed. Challenges affecting the adoption of AI and ML in the construction sector might have been overlooked given that the study targeted only three databases, namely Google Scholar, Scopus, and Web of Science. Therefore, it is possible that the results of this research do not reflect the entire spectrum of the literature concerning the application of AI and ML within the lifecycle of a building project. It is vital to consider that in the fast-growing world of AI, more often than not, companies may face great opportunities and challenges within a very short period of time while the outcome might be different for every enterprise. Stemming from the above review of the literature, this paper sought to give an overview of the numerous applications of AI and ML in building trades. Of course, interviews and survey questions to construction site employees would have offered a better understanding of the applicability or drawbacks of these technologies and real-life experiments could not be conducted with additional datasets including sensitive information. For this reason, the methodological approaches offered in the works analyzed in this investigation should be supplemented with more comprehensive research that explores case studies. Since the general application of AI and ML in the construction industry has been discussed, the case should be included to provide more detailed information.

V. CONCLUSION

AI and ML are still on the way to affect several industries positively since they are a new approach to modern solutions and increased production rates. AI and ML can enhance the building process by integrating the data generated throughout the building's life cycle and working with other technologies, systems, and devices. In order to respond to the research objectives set out and aimed to answer, this study considered the ways in which AI and ML were applied throughout the BLiCS. We also reviewed the studies in the last 12 years together with the older ones for different building-related outputs and purposes. Classification and understanding of artificial intelligence (AI), its components, kinds, and subfields are explained, as well as works that incorporate AI and ML.The paper presents the discussion of the AI and ML applications in the construction of buildings and structures and examined their uses and benefits at different stages of the construction process.Due to the pattern identified in the trends of AI and ML related publications, our study applied a qualitative research method. The relevant databases that were Google Scholar, Web of Science,

and Scopus were among the many platforms that were searched for.

The search spanned a period of many decades which exposed the participants to high risks. Therefore, these databases were selected to minimize bias because they are well-known to be reliable and contain credible sources of information. The mentioned data can then be utilised to talk about and get AI as well as ML applications in building research on top of the life cycle foundation. It has been ascertained, however, that the most benefits of AI and ML application can be received at the design and construction stages of a project. Thus, making use of the mentioned techniques in the field of construction, the research identified that recent advancements have brought improvements in the industry to the table. A particular area that has been rather slow in adopting advanced AI tools has been the construction sector, even though the potential benefits are significant. It should be noted that more potential has not been paid to deep learning despite the fact that it does promise even more accurate forecasts as compared to standard machine learning strategies. Although the overall concept is relatively new and the industry behind it is just starting, there are still a lot of options for the construction industry in terms of the usage of AI and ML. It is relevant in this research work to put more emphasis on the above highlights as major achievements in this field.

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