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Adoption of Artificial Intelligence for Optimum Productivity in the Construction Industry

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ABSTRACT

The construction sector has begun to embrace the digital revolution, intending to improve efficiency. How, on the other hand, should the industry adopt digital tools? And how should the connection between humans and technology function? This study aims to shed light on how the construction sector may bridge the gap between AI deployments's potential and realized advantages. This article presents research based on a comprehensive review of the literature, case studies of Speller Metcalfe, a design-build and refurbishment project in Malvern, England, Jacobsen Construction, a project digitizing the planning process in Salt Lake City, Utah, USA, and Menkes Development Inc., real-time visibility to construction site insights and data-driven decision-making in Toronto, Canada. The experiences gained via this study show that it is feasible to acquire expertise while adopting sophisticated technologies, such as artificial intelligence, by installing fundamental digital tools (AI). However, when it comes to AI, the level of trust between humans and machines will be the deciding element in its success. This article is a pioneering effort in examining the deployment of AI and how people and technology should interact. This study is limited to three case studies and three digital technologies. To further the study, it is suggested to debate the adaptation of AI on the user's premises, gather more empirical data, and examine case studies from different sectors.

KEYWORDS

Commitment, Collaboration, Trust, Construction projects, Artificial Intelligence

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INTRODUCTION

The construction industry is presently transitioning from hierarchical, conventional building sites to more autonomous, digital ones. A digital revolution is underway, and the advancement of digital technology is accelerating at such a rate that the industry is struggling to stay up. This paper is part of a collection of groundbreaking research.

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As it examines the application of artificial intelligence. The use of artificial intelligence is a relatively new field of study, particularly in the construction sector. AI can automate many processes and improve the efficiency of the construction process. This is consistent with the lean philosophy, which places a premium on reducing waste and increasing value. Based on the above, this article aims to shed light on how the construction industry may bridge the gap between the potential and realized advantages of AI deployment. Two research topics have been created to identify a method to close the gap.

1. What are the possible advantages of incorporating artificial intelligence into the building industry?

2. How is the construction sector now reaping the rewards of AI implementation?

This paper is limited to case studies of Speller Metcalfe, a design-build and refurbishment project in Malvern, England, Jacobsen Construction, a project digitizing the planning process in Salt Lake City, Utah, USA, and Menkes Development Inc., a project providing real-time visibility to construction site insights and data-driven decision-making in Toronto, Canada. Five digital tools are the subject of the case studies (Fieldwire, Touchplan, Procore, CISCO packet tracer and PVsyst photovoltaic). Additionally, the authors drew on data on lean manufacturing, last planner system (LPS) adoption, low levels of digitalization, and other sectors. The paper is structured as follows: a method chapter, a theoretical framework, results and discussion, and a conclusion and recommendations for further study.

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LITERATURE REVIEW

Science is about improving on what has already been discovered. Research and literature searches were carried out in order to gain a general overview of the most recent research and literature. The basic research on the implementation procedure and general digitalization of construction project planning was mapped out by the literature search and analysis. Based on the available literature, the chosen case studies, and the author's interest in artificial intelligence, the Dr. Philos thesis was limited to examining the use of AI-based technologies. The methodology used for the literature review is described in The following sections will be arranged in the following order:
1. Recognize and collect literature
2. Review of Literature
3. A literary examination
4. Theoretical foundations
A variety of reliable databases, journals, conference papers, articles, books, snowballing, and supervisor recommendations were used to perform the literature review. The proposed content was selected and utilized as a starting point for additional research utilizing search engines after discussions and supervision. The search engines used were Scopus, Elsevier, Science Direct, Mendeley, Google Scholar, and Google. A more thorough overview of the databases is available via search engines. The chance of finding relevant content increased due to the size of the databases examined. However, a search method must be devised in order to find relevant content in all databases. The author started by doing an extensive search of the most widely read and quoted literature. Later, only credible and relevant information was included in the search. The following queries were used to assess the relevancy and caliber of sources:

1. Is the literature relevant to the topic?
2. In what places was the material released?
3. In what year was the book released?
Is the literature subjected to peer review?
5. Is the IMRAD 4 format used in the literature?
6. Is the research approach reputable?
7. Has the author consulted up-to-date, trustworthy sources?
8. What is the author's h-index 5?
Figure 1 shows that there was a lot of information on each subject (implementation/human AND behavior and AI).

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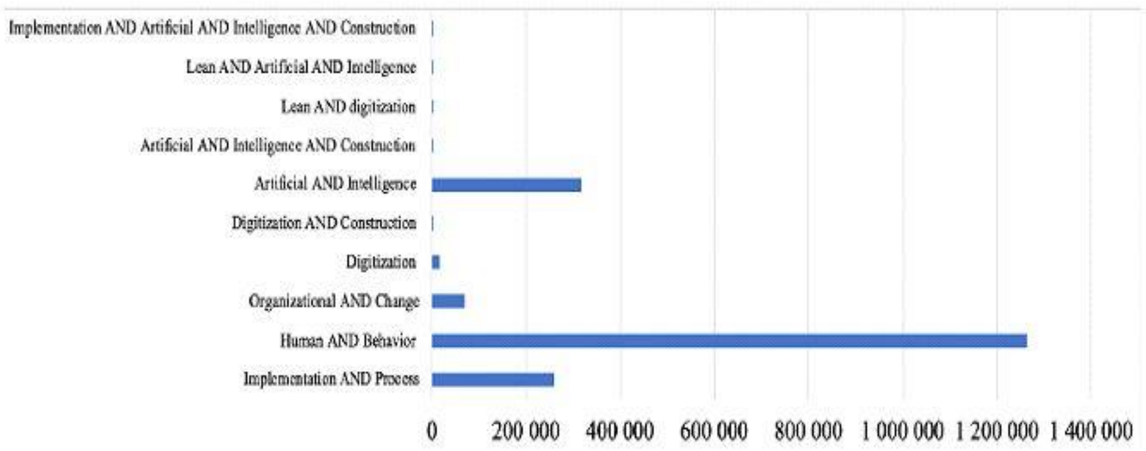
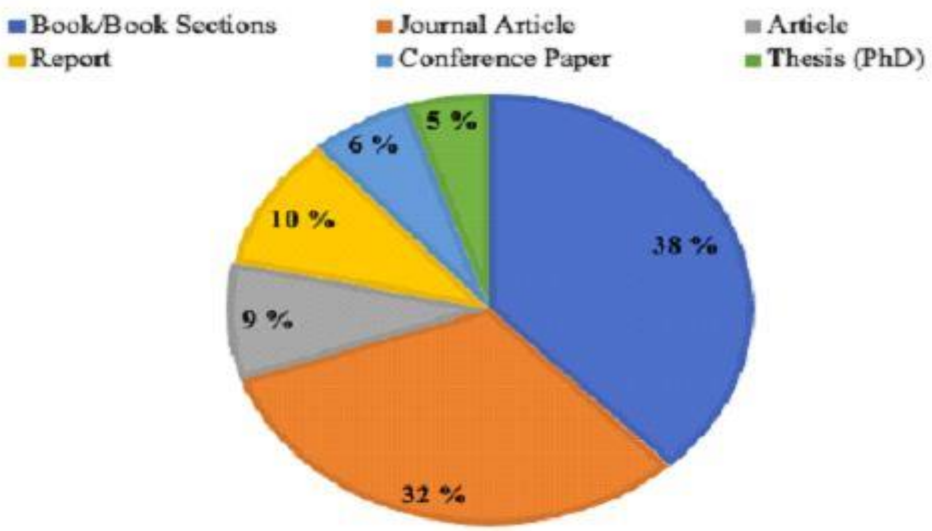


Fig 1: Searching terms and the search engine scopus hit count

The chosen literature was read in accordance with the minimum quality and relevance requirements mentioned in the previous list. The cmd (f) search function was used to find relevant information in digital books and articles. The literature was evaluated further utilizing the reliability-objectivity-accuracy-aptitude framework (ROAA). In addition to passing the ROAA principle evaluation, the majority of the bibliography is comprised of sources that match the criteria in the preceding list. Figure 2 depicts the diversity of sources listed in the figure.

Fig 2: The presentation of sources

Numerous challenges have slowed the construction industry's development and lowered its productivity compared to manufacturing. The construction industry is one of the least digitized globally, and most stakeholders are resistant to change owing to its manual nature. Inadequate digital knowledge and technology adoption in construction has been linked to costing inefficiencies, project delays, poor quality performance, ill-informed decision-making, and poor productivity, health, and safety performance. In recent years, it has been clear that the construction business must embrace digitization and swiftly improve technical skills, especially given current manpower shortages, the COVID-19 pandemic, and the need to create sustainable infrastructures. In recent years, AI has improved corporate operations, service processes, and industrial production. AI has automated processes and brings competitive advantages over older approaches. Machine learning, NLP, robotics, computer vision, optimization, automated planning, and scheduling are AI sub-fields used to solve



complex problems and make decisions for real-world concerns. In manufacturing, Industry 4.0 focuses on automation, data-driven technologies, and AI methodologies. This revolution has improved processes, reduced costs, shortened production times, improved safety, and helped companies fulfill sustainability goals. Despite these difficulties, AI has yet to benefit construction. For decades, artificial intelligence and its subfields have been used to solve building challenges. Machine learning is used to monitor health and safety, evaluate costs, optimize supply chains and logistics, and forecast risks. Robots monitor and analyze site performance, conduct offsite assembly, and handle construction materials, plants, and equipment. Knowledge-based systems can assess bids, mediate disagreements, manage risk

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and waste, and evaluate sustainability. Construction is one of the least digitalized industries on the globe, and it struggles to integrate AI and other digital technologies. Several studies attribute the lack of AI adoption to cultural challenges, high initial prices, trust, security, talent shortages, computer capacity, and internet availability. Artificial intelligence applications, future potential, and adoption difficulties in the construction industry include various grey areas. China, the U.S., and India account for 57% of global construction demand, which accounts for 13% of global GDP. Global infrastructure investment might reach $3.4 trillion per year by 2030, or 4% of GDP. The industry accounts for 3% of Nigeria's overall economic production, 4.3% of Germany's, 6% of the UK's, 4.1% and 6.8% of the US'. According to the Project Management Institute, a project is a temporary endeavor to develop a unique product, service, or result. Early project management ideas trace back to the ancient Egyptians' pyramid building and have since been refined into an established discipline. Due to their intricacy and changeability, building projects generally yield unique things, not mass-produced ones. Companies started using specialized tools and processes for big projects in the 1950s. Despite a lengthy history of project management, building projects worldwide have experienced poor performance, including cost overruns, schedule delays, and low-quality products. This requires a rigorous analysis of the industry's present project management procedures and the identification of opportunities for improvement. Planned construction projects are necessary and complex because they include a sequence of procedures that must be completed concurrently to satisfy the project's objectives. Another source says project planning comprises of requirements, technology accessibility, specified scope, resource allocations, team building, and identifying procedures that cause these associated tasks to be completed. For details, A construction project plan must address all elements of construction from the beginning to the end. Project management knowledge domains and the project environment work together to make it harder to plan so that time, money, and quality limits are met. To ensure the paper's quality, it was important to analyze the sources' validity, reliability, and generalizability. A search approach was utilized to acquire high-quality content. This project will connect existing and future AI construction usage. Valid literature refers to the work of notable authors on the topic. This research is reliable. This study contacted AI and human-AI collaboration authors. The authors were found via a search approach, and the AI elements came from many sources. Peer-reviewed journal papers summarize current research. Specialists manufacture them. In reports and publications McKinsey's non-peer-reviewed reports are one example. Although information and articles include authors' names, competence, and publication date, one must be skeptical. McKinsey & Company seeks new clients. The sources aren't impartial.

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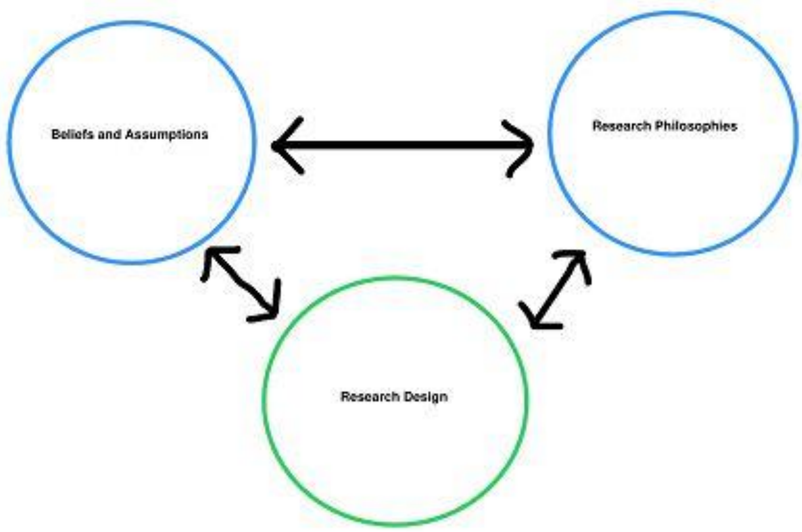
The use of artificial intelligence for construction project planning is well-documented. The author had to rely on his or her experiences from other fields, like IT, which could be used to plan a construction project.

METHODOLOGY

This paper explains the research methodology. Research methodology addresses the research topic using an organised work plan. This includes data gathering, creating linkages between variables, and accuracy before objective assessment. Correct research begins with a thorough review of existing studies and literature. Literature reveals a knowledge gap. Creating research topics helps bridge the knowledge gap. Many methodological considerations must be made for high-quality, trustworthy research. Each choice influences the next. This section explains the thesis's methodology. Research philosophy is "beliefs and assumptions regarding knowledge development." As with everything else in life, our beliefs and assumptions impact our everyday choices. We create assumptions at every level of research, which impacts the researcher's approach, data collection, and analytic data. Reflection is needed to determine the research philosophy. This shows where the researcher's views overlap or deviate from the five philosophies. The HARP tool facilitates this contemplative process. It helps define study values and explains and justifies the research design. Research philosophy is the researcher's views and assumptions regarding knowledge development. Our beliefs and assumptions impact our everyday choices, consciously or not. At every level of research, we make assumptions that affect the researcher's technique, data collection, analysis, and utilization. Reflection is needed to determine the research philosophy. This shows where the researcher's views overlap or deviate from the five philosophies. The HARP tool facilitates this contemplative process. It helps define study values and explains and justifies the research design.



Due to the vague study questions, purpose, and knowledge gap revealed throughout the literature search, This investigation was also qualitative. Qualitative research involves a comprehensive design. Uncharted territory means a vast amount of data is needed for a quantitative approach. Comparatively, qualitative procedures are more subjective. Inaccuracy may originate from the author's interpretation of the data. Triangulation, comprising literature reviews and case studies, was used to increase the research's validity and reliability. A literature review was used to find prior research on the topic, identify knowledge gaps, and improve the author's understanding. The literature search revealed no written material on AI in building project planning, highlighting the necessity for a thorough research design and qualitative methods. Since AI-based initiatives in England, the US, and Canada need a lot of data, quantitative approaches are hard. The research focused on three AI-savvy companies (Fieldwire, Touchplan, and Procore). Given the project participants' awareness of AI, the amount of digital tool deployment, and the purpose of the study, case studies are a good data collection method. Three firms were asked about AI-based construction planning. To get expertise and experience, we contacted three firms. Case studies allowed informal talks and observations alongside the methodical investigation. The author attended webinars on all five digital tools (Fieldwire, Procore, Touchplan, CISCO packet tracer, and PVsyst). The author attended a course called "Artificial Intelligence in the 4IR" to learn more about AI. Even though they weren't organised research, case studies, webinars, and the AI course helped the paper.Choose a research approach that best answers the study questions and project's objectives. Project management uses experiment, survey, archival research, history, and case studies. The case study method is used to explain why social phenomena behave as they do. This paper attempts to connect existing and future AI construction implementations. Three case studies were chosen for data gathering and analysis depending on the research's goal. Conscious data collection from several sources improves study quality and validity. Instance studies may be a series or a single case. Numerous case studies gather data from diverse contexts, such as multiple building projects. One case study compiles data from a particular building project. In the absence of research on a phenomenon's extent and context, a single case study may be useful. The two main problems with a single case study are less transferrable results and the effect of other circumstances. Many case studies were chosen due to a lack of research. The case study's tale and background must be presented as a narrative for the qualitative research analysis and outcomes to be convincing. The following facts were acquired from construction software vendor websites, live webinars, slide notes from a Fieldwire senior manager, emails from Procore (formerly INDUS.AI) and a

Touchplan senior business development person assigned to the project. Choose a research approach that best answers the study questions and project's objectives. Project management uses experiment, survey, archival research, history, and case studies. The case study method is used to explain why social phenomena behave as they do. This project intends to connect existing and future AI construction implementations. Three case studies were chosen for data gathering and analysis depending on the research's goal. Conscious data collection from several sources improves study quality and validity. Instance studies may be a series or a single case. Numerous case studies gather data from diverse contexts, such as multiple building projects. One case study compiles data from a particular building project. In the absence of research on a phenomenon's extent and context, a single case study may be useful. The two main problems with a single case study are less transferred results and the effect of other circumstances. Many case studies were chosen due to a lack of research. The case study's tale and background must be presented as a narrative for the qualitative research analysis and outcomes to be convincing. The following facts were acquired from construction software vendor websites, live webinars, slide notes from a Fieldwire senior manager, emails from Procore (formerly INDUS.AI) and a Touchplan senior business development person assigned to the project.

Fig 4: Speller Metcalfe uses Fieldwire to improve collaboration on the job-site and keep production moving on schedule without any costly delays.

THEORETICAL FRAMEWORK

Research requires reading, evaluating, and being inspired by others' work. This goal is to map how the assigned topics have been covered and studied in previous research and to identify knowledge gaps about how the subjects connect and rely on each other. The construction industry is non-digitized with slow productivity development. Digital technology might enhance production productivity, according to studies. AI and other technologies are

currently available. There's little written about AI in buildings. Therefore, research on AI implementation and human behavior must be combined. The author has investigated human-AI collaboration in AI-focused sectors. The theoretical framework has three key sections:

1. Implementation change 2. AI (AI) 3.Human-machine interaction

Implementation is the process of putting a new idea, programme, or set of activities and structures into action. Implementation transforms. Figure 5 demonstrates a four-stage transition process. In Phase 1, the organisation must decide whether the proposed change is advantageous. Relevant people should evaluate the modification and oversee its implementation. In Phase 2, the implementation framework, a thorough evaluation of flaws and potential is the basis for a strategy. Phase 2 determines implementation needs. The third phase involves implementing phase 2's strategy and plans. Fourth-phase participants should analyse what worked, what didn't, and how to enhance implementation.

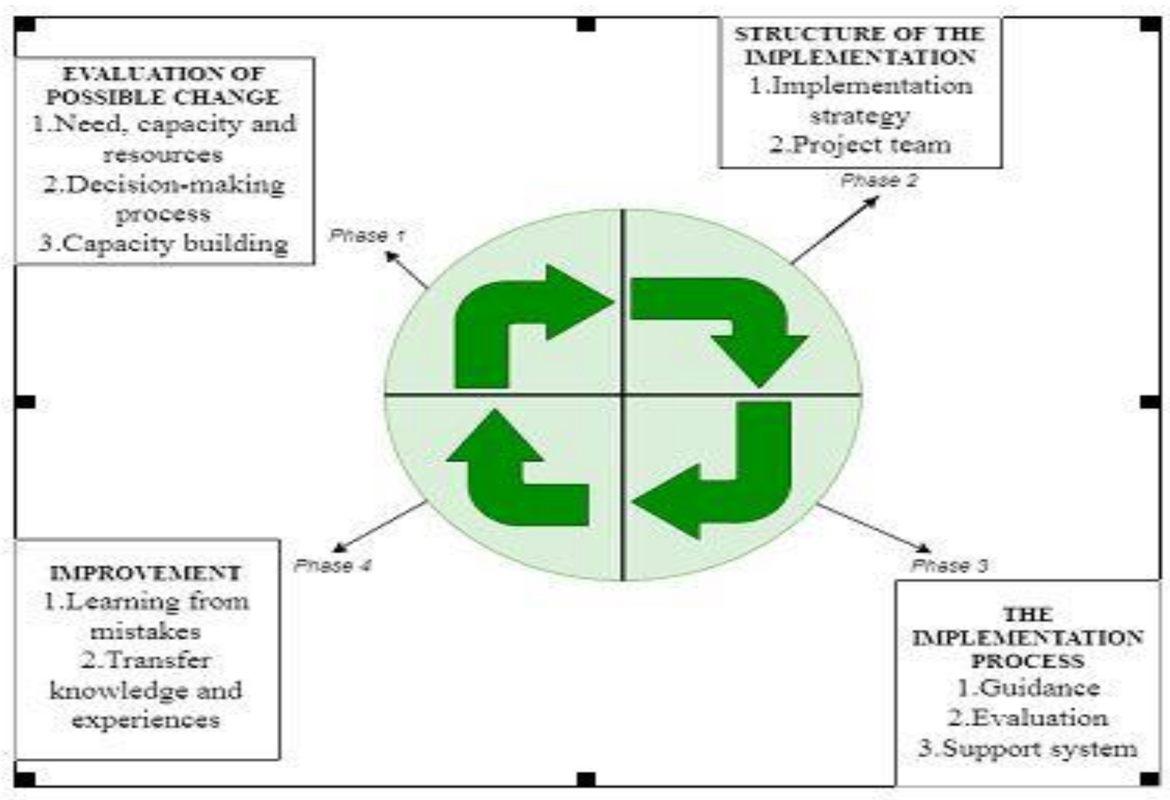
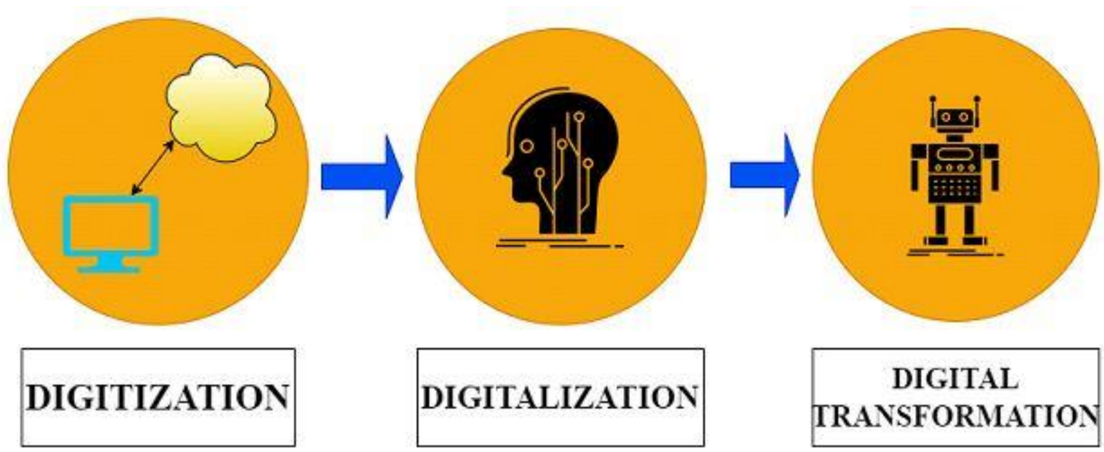


Fig 5: Implementation model

The transition to digital has taken place in the construction industry as part of an attempt to increase output. Although not to the same extent as in other sectors and with very little impact on the sector's overall production efficiency, some technologies have been introduced in the sector over the course of the previous four decades. Will artificial intelligence be the technology that utterly revolutionizes a sector? It is generally known that the adoption rate of AI-based technologies in the construction industry is very close to 0 percent. According to them, "artificial intelligence [is] the next frontier for the building sector." Compared to other industries, using AI-based technology to cut costs, improve risk management, and boost production has a number of clear advantages.

Fig 6: Digitization, digitalization and digital transformation (Made by the writer).

AI is a scientific field, comparable to mathematics and biology. Thus, AI is a collection of ideas, issues, and problem-solving techniques.AI is built on a number of sub-fields and is itself a sub-field of Computer Science (CS). AI is a sub-field of computer science that focuses on constructing intelligent computers that can do specialized activities as well as humans, or even better. As is the case with the term "digital," several meanings of AI exist. For some, AI refers to artificial life-forms that transcend human intellect, while for others, the term may be used for nearly any data processing technique. Even AI researchers do not possess a precise concept of AI. The following is one of numerous definitions:The ability of a computer to act like a smart person by using algorithms that are inspired by people to solve problems that have always been hard.John McCarthy (1927–2011) is believed to be the founder of AI. McCarthy planned the Dartmouth Conference, which was conducted for the first time in 1956 at Dartmouth College in New Hampshire, United States of America. McCarthy picked AI as



the subject for the seminar, which was dubbed the Dartmouth Conference. The word was derived from the following assertion:

Any aspect of intelligence may be broken down into processes so basic and mechanical that each step can be codified as a computer programme.

This assertion cannot be proven true. Nonetheless, the concept it presents is crucial when considering AI. AI-based systems may be created to do a variety of activities, including voice recognition, in order to learn, perceive, plan, and solve real-world issues. But for these systems to work, they need a lot of data from the real world.Humans and technology are separated in traditional society. However, recent technology advancements have led to the creation of sophisticated automation that can perform better than a person in some instances.Humans cannot compete with AI-based technology when it comes to the analysis of data, information, and knowledge; similarly, AI-based technology cannot compete with a human's ability for pedagogy, creativity, visionary thinking, and ethics. To optimize creative behavior, people and technology must work in a way that combines their respective abilities. However, what will cooperation between AI-based technologies and people demand of AI-systems and what will they need of humans?Until recently, AI-based technology research concentrated on new algorithms rather than the usability, practical interpret-ability, and effectiveness of actual people. This section describes, according to the literature, the conditions for a successful human-AI partnership. As stated before, there is a dearth of research on the use of AI in the construction business. Most of the information here comes from the information technology, manufacturing, and health care industries.Figure 7 demonstrates that the integration of the user (human) and the tool (machine) to accomplish a specific task is just one aspect of any mission. The physical medium and social context must also be addressed, as well as the managerial function. Management is the vital connection between humans, machines, and the objective because it ensures that staff are properly trained. To accomplish the task, both the machine and the human interact within the physical medium and management. The subsequent part will concentrate on how human and machine cooperation should operate.

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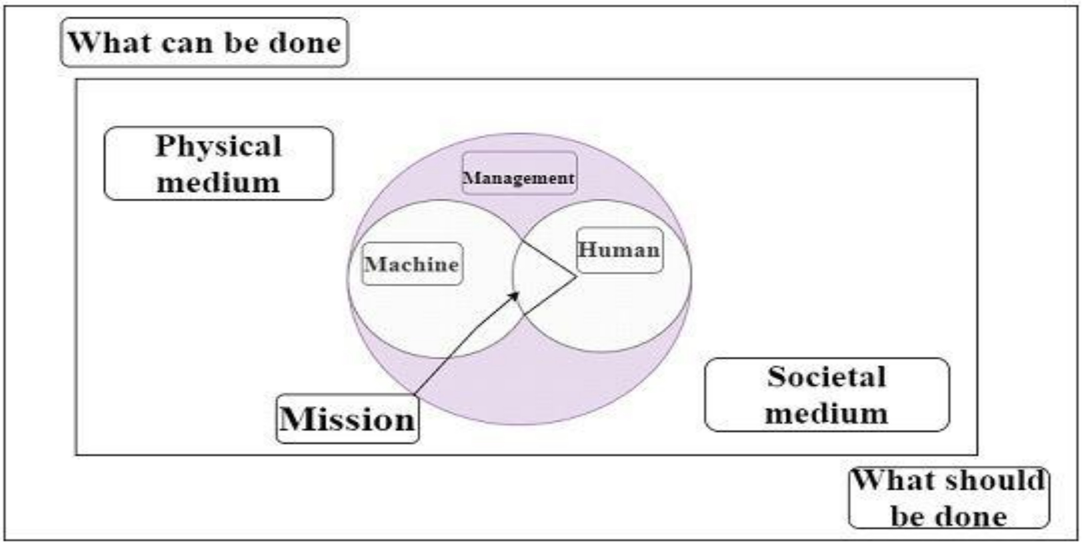

Fig 7: The five M's framework

The basis for machines is data. There is a paucity of data collection in several businesses, including the construction industry. If data exists, it is often restricted to a subset of users who can access and comprehend the associated domain system. For non-AI engineers, who are often the users of AI-based technologies, problems such as "Can users confirm that the AI-system has not acquired a skewed perspective of the world due to deficiencies in the training data or objective function?" emerge.. "Can consumers have faith in the dependability of AI systems without an explanation of how they arrived at their conclusions?" "Would a physician operate on a patient because the model suggested it?" According to current studies, the majority of consumers will want an explanation in order to determine whether they should trust or mistrust AI-systems. How does the system arrive at a certain forecast and suggestion, and how does it determine whether or not it is a good solution? Lack of confidence in AI-systems is one reason why AI-based technology adoption remains low in application domains where explain-ability is beneficial or even needed. Just as effective human-human collaboration involves clearly defined roles and duties, so will human-AI cooperation. In order to build trust and further establish a functioning human-AI partnership, contact between humans and AI-based technology is required. A fundamental difficulty associated with this is

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determining how and what to disclose to users in order to gain their understanding and confidence without exposing them to the potentially vast amounts of data necessary to train the network and by the system to make choices. A data format that can be readily understood by both humans and AI-based technology is required. Nevertheless, determining the content of such an explanation might be challenging.

FINDINGS

Touchplan is a daily construction planning programme that increases the predictability and profitability of project results. Touchplan is the most collaborative platform for planning, re-planning, and optimizing daily recuperation, with the most up-to-date data and insights from the work site. Touchplan has conducted a poll to determine the effect that construction planning software has on construction project management. This survey was done in conjunction with the Lean Construction Institute and was sent to members on February 18, 2022. Over 110 individuals from 63 of the major companies in the United States responded to this study. 86 percent of respondents reported using digital planning tools to oversee their building projects. As a result of using construction planning software, 95 percent of respondents are confident that it has a favorable return on investment and pays for itself quickly. This thesis examines how Touchplan was created to give a more organised method that helps you attain more confidence and predictability. Utilizing construction planning software will save time on projects. This significantly reduces the amount of rework required to accomplish a project. Reduce the number of project hand-offs that are missed. Normalize your procedures. Reduce daily phone calls, text messages, and email.The majority of respondents to the poll are general contractors. (65 percent)The majority of poll participants support Lean Construction and the Last Planner System®. (65 percent).

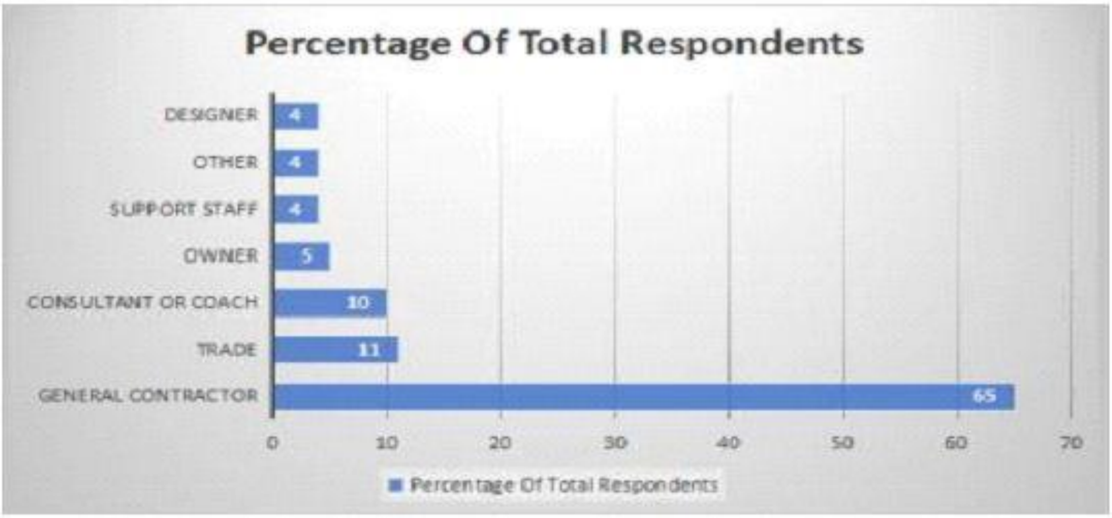

Fig 8: Percentage Of Total Respondent

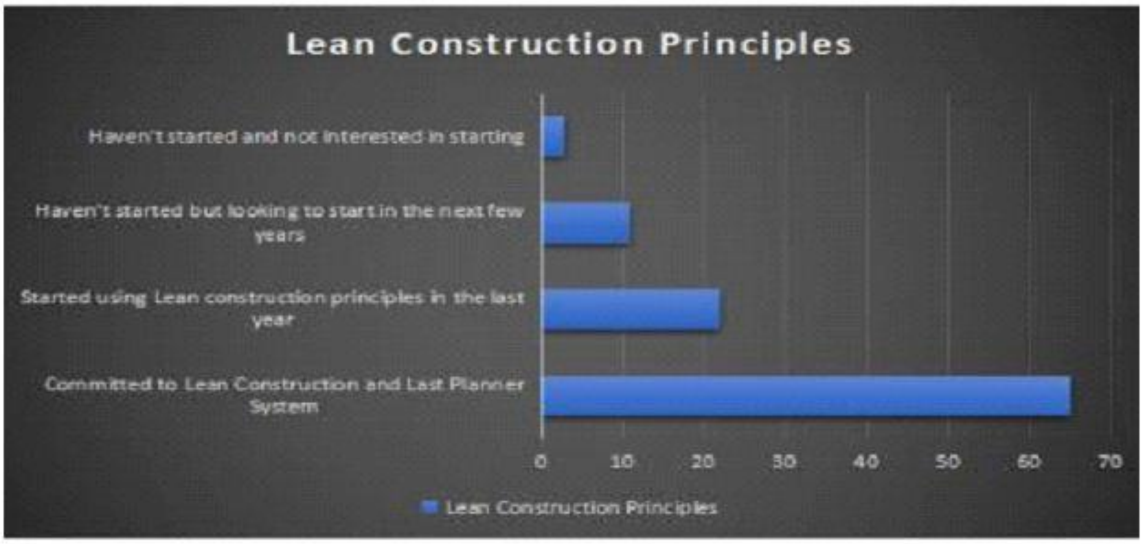

Fig 9: Lean Construction Principles

The construction industry in 2022 is plagued with pandemic hangovers: delayed or cancelled projects; supply chain problems; pricing rises; delivery delays; and most urgently, a manpower crisis accompanied by an unprecedented mass exodus. As burdensome as the epidemic is, it has pushed the sector into the digital arena.In the face of a labor shortage of crisis proportions, enterprises are prioritizing technology to maximize efficiency, enhance profitability, improve worksite quality and safety, and retain top personnel. As evidence of this digital shift, construction technology investors' financing hit a new high of $2.1 billion in 2021, an increase of more than 100 percent from the previous year. As the industry responds simultaneously to these difficulties and new digital opportunities, construction technology continues to bring workers together to allow improved cooperation across the whole project life-cycle. This portion of the thesis examines in detail how our clients distinguish themselves from their competition by enabling their employees to do their best job using Procore. By supporting more collaborative project delivery from pre-construction through closeout, our clients unlock the productivity of their staff for a more predictable and lucrative business. We think that, in the end, this book will help you do what construction has always done: figure out how to solve the problems of building the world and our future together.A global survey of 2,687 Procore customers, including those from North, Central, and South America, the Caribbean, Asia, Europe, Australia, and New Zealand. The data includes all sizes of general contractors, specialty contractors, and owners are included in the data. All survey answers are self-reported, and unless otherwise stated, all references to customers, users, or any other stakeholder group refer to the population polled.

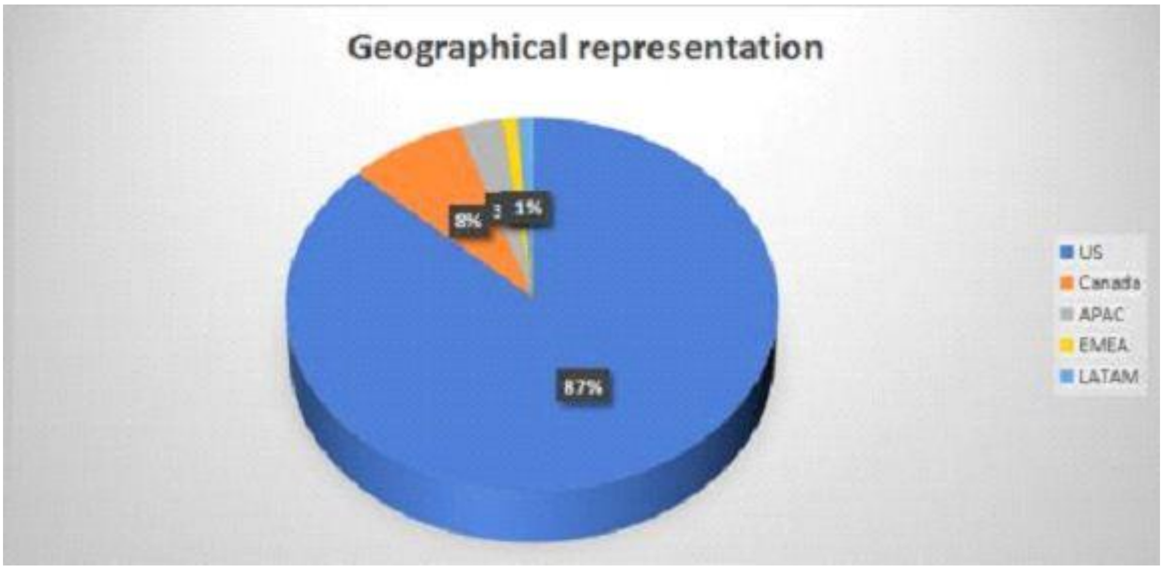

Fig 10: Geographical representation of global survey participants

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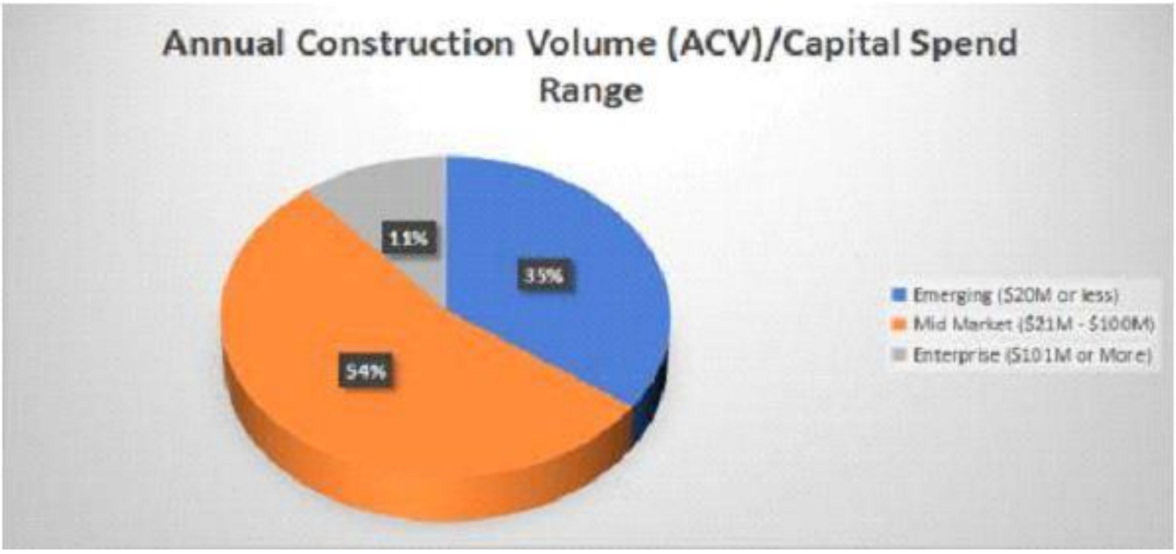
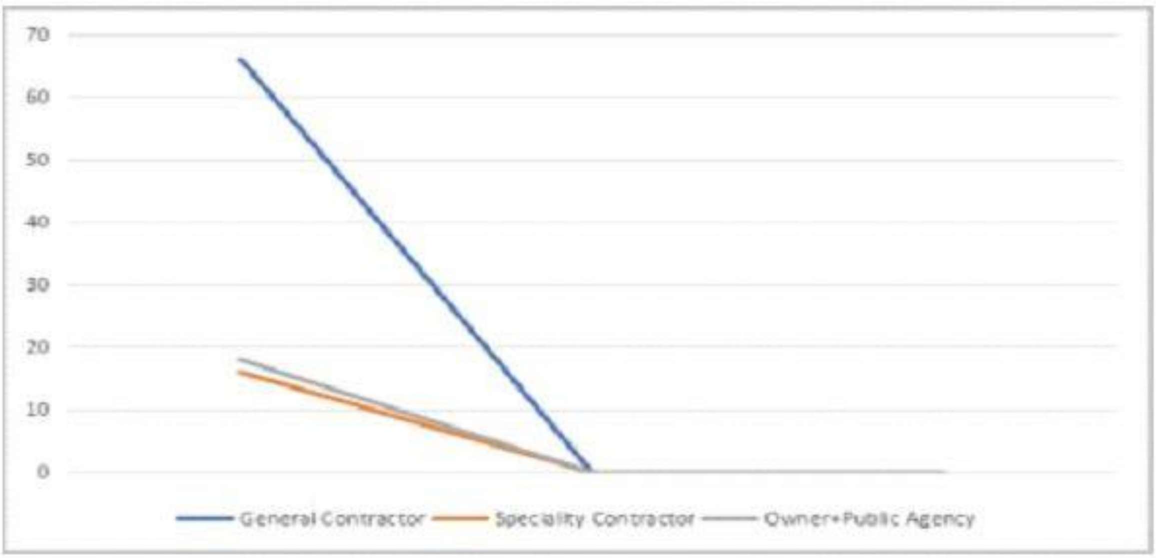


Fig 11: Annual construction volume/Capital spend range

Fig 12: Audience between general contractor, speciality contractor and owner+public agency

DISCUSSION

This section demonstrates various AI-based construction sector applications. The capacity of machine learning to examine large data sets and learn from experience may be used as a decision-making aid. Among other applications, pattern recognition may be used for site monitoring and construction verification. Monitoring the site may improve site safety, whilst construction verification is likely to save hundreds of hours compared to human verification. Several startups evaluating the use of machine learning and pattern recognition are now attempting to enter the market. This research also demonstrates that robots can be used on building sites. However, they are only employed to do repetitive jobs in a controlled setting at present. To realize the advantages, various obstacles must be eliminated. The following section will elaborate.Any AI system (including machine learning, pattern recognition, and



robotics) must have adequate data, high-quality data, and the appropriate variables. The results indicate that pattern recognition is commonly used in the healthcare business to identify illnesses in their earliest stages. Globally, medical offices and hospitals are partnering to continually generate more data. Consequently, AI-systems are continually growing more accurate, precise, and thus reliable. Can the construction business use these lessons and gain knowledge from the healthcare sector?One may argue that each building project is unique, but the human body consists of identical parts. Given that each building project is unique, it will be difficult to gather data that can be properly transferred across projects. To put it another way, it is apparent that each building project is unique when seen from a holistic perspective. They are placed in diverse geographic locations and have distinct appearances, such as facades, windows, etc. However, when each construction project is broken down into its component elements, is each project as unique and difficult as it first appears? It is feasible to disassemble the whole structure into smaller components. We begin by observing the whole structure, then the concrete structure, then all of the concrete slabs, and finally a single concrete slab. How many methods are there to construct a concrete slab? Not quite as numerous as the number of illnesses that may develop in the human body, much less the variety of reasons for these disorders. The more data is supplied to an AI system, the more exact and reliable its findings will be . Logically, the collection of data will be accelerated if several construction projects create data concurrently, much as medical offices and hospitals throughout the globe collaborate. Due to the competitive nature of the construction sector, close cooperation between enterprises has not been the norm. Nevertheless, the lean mindset, with its emphasis on cooperation and increasing efficiency by eliminating non-productive elements, has now penetrated the construction sector. Collaboration between companies to gather data may be seen as an act of eliminating what is ineffective. Which companies will own the acquired data will be a significant topic of discussion and a problem to be addressed in the future. As assert, is a partnership based on agreements sufficient to assure that all enterprises maximize the advantage of all partners? How should subcontractors be paid if the AI system figures out the safest, most productive, and least expensive way to build a certain part? Even more crucial than the quantity of data generated is the quality of the data produced. According to, it is not sufficient to have a substantial quantity of data from prior instances; the data must reflect the actual condition. It must be accurate in order to assist people in their jobs since AI-based algorithms learn from the provided data and create predictions based on the data learned. Given that the construction industry is project-based and consists of a large number of specialized co-

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workers working on the same construction project for a short period of time, communicating the importance of providing correct input data may be difficult.

CONCLUSION AND FURTHER RESEARCH

This next section provides responses to the two research questions and clarifies the goal of this report on the doctorate thesis, as outlined in the first chapter of the report (the introduction). In conclusion, several suggestions are offered regarding the direction of future study. This thesis is a groundbreaking piece of work since it analyses the use of artificial intelligence (AI) in the construction sector and how people and AI-based technology should operate together. The investigation has been carried out in the form of a review of the relevant literature and a number of separate case studies. The employees who were selected come from a wide range of backgrounds in terms of their jobs, levels of expertise, ages, and general views regarding AI. In light of the fact that there were employees from a variety of backgrounds, it is reasonable to infer that the results of this research may be extrapolated to future projects both in Norway and in other countries, such as South Africa. The purpose of this study was to provide answers to the research questions that were based on the difficulties that are present in the current practices of construction project planning, the AI solutions that are currently available, and the justification for a better and more widespread implementation of AI in construction project planning.The first research question, which will be answered in the next part, is as follows: What are the possible advantages of applying AI in the construction industry? It is possible to draw the conclusion that AI is here to stay, and there are many advantages associated with putting AI into practice.The potential benefits that can be gained from the three categories of technology, process, and culture are outlined in Figure 13, along with how they can collectively reshape the building and construction industry by making the building process more efficient and secure, as well as by improving the overall quality of buildings and other structures.

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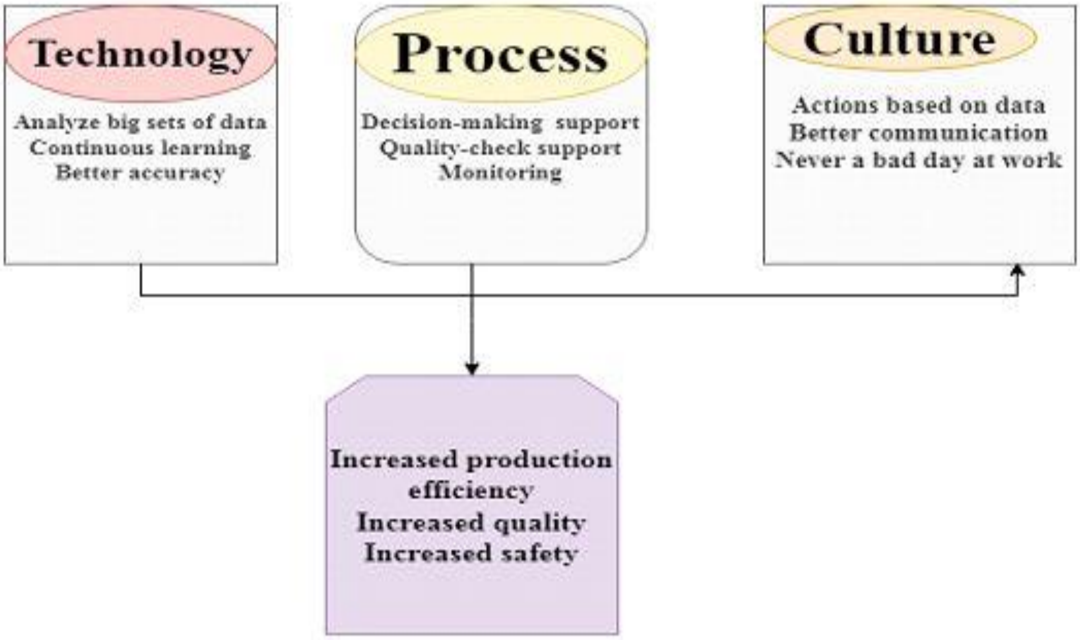

This study has shed light on a number of interesting themes, and it is suggested that more investigation be conducted on these areas. The study that has been carried out does suggest, however, that in the future there will be tighter cooperation across nations. In this vein, it could be fascinating to study issues of ownership and trust amongst individuals who have either never met each other in person or have done so just a limited number of times.The scope of this research was restricted to examining how artificial intelligence-based technology is being used in the construction business. However, because of the increasing digitization of society as a whole, it could be interesting to investigate the possibility of using AI-based technology during the design phase of building, as well as throughout the phases of operation and maintenance. To map how much openness and human-AI contact is required in the AI-system in order to acquire an adequate degree of human-AI confidence would be another intriguing subject to research, and it would be helpful to do so. In light of this, conducting a survey that has questions that are quite precise could be an appropriate way to gather data. Throughout the course of this investigation, a number of obstacles came to light, which served as a source of inspiration for the formulation of the following set of suggestions for further research:

• When compared to other industries, the construction sector receives an insufficient amount of funding for scientific research that is related to artificial intelligence solutions that are being created for project management. This is an area that requires more attention, particularly in view of the fact that an increasing number of employment functions are anticipated to be supported by technology in some form or another. This is an area that needs more attention. Therefore, the first suggestion that can be made for further research is to investigate AI-based solutions from a strictly scientific point of view for certain functionalities that were covered in this study.

• Because the focus of this study was primarily on project management and planning functions for the construction industry, one of the recommendations would be to investigate artificial intelligence systems for other aspects of the industry, such as detailed engineering design and facility maintenance.

• Another recommendation would be to investigate different individual demographics, such as male and female perspectives, geography, and culture, in order to understand the challenges that these factors present. Another recommendation would be to investigate the government programmed and policies that are already in place that influence the adoption rate of organisations. This would be done in order to provide a better incentive for organisations to use these advanced technologies and processes for construction projects, such as Building Information Modeling (BIM) and Artificial Intelligence (AI).

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