Can Artificial Intelligence be a Critical Success Factor of Construction Projects?: Project practitioners' perspectives

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"Although the original vision for artificial intelligence was the simulation of (implicitly human) intelligence, research has gradually shifted to autonomous systems that compete with people."

Susan L. Epstein (2015)

The construction sector has not been altogether successful in adopting automated systems. Related research on artificial intelligence has mainly been confined to the development of software models for a specific subset of construction work. This study aims to identify whether artificial intelligence is a potential critical success factor for construction project success. Data were collected through semi-structured interviews and analyzed using content analysis. The interviewees were selected on the basis of convenience and included highly experienced project managers from the global community with expertise in project management working on large construction projects. Our research shows that senior project managers perceive artificial intelligence as different from information technology and advanced project management software. Major drawbacks of artificial intelligence were found to be (i) lack of soft skills, (ii) lack of intelligence to interpret things in various ways like human beings, and (iii) lack of human relationship capabilities, including the ways people manage projects. The interviewees believe that artificial intelligence is still years away from becoming self-aware. This study improves the understanding of artificial intelligence as a success factor for construction projects and provides future directions for research in this field.

Introduction

Artificial Intelligence (AI) can be defined as constructing computer programs that (i) are capable of exhibiting intelligence, (ii) exhibit intelligence by using processes used by humans for the same tasks, and (iii) are capable of complementing or supplementing human intelligence (Simon, 1995). As Epstein said (2015), "Although the original vision for artificial intelligence was the simulation of (implicitly human) intelligence, research has gradually shifted to autonomous systems that compete with people". Artificial neural networks, machine learning, genetic algorithms, fuzzy logic, and statistical analysis form the basis of most applications under the label of "AI".

The role of AI and how it is transforming companies are not well studied (Kulkov, 2021). Despite its great potential for solving problems, there are still issues involved in its practical uses (Borges et al., 2021). Overpraised and highly criticized, AI died at least four times in five decades because of wild claims made by people and research about AI. Instead, we focus here on the best machine intelligence one can construct without regard to what people can do (Epstein, 2015), given that advances in AI research have mainly been in isolated silos (Loureiro et al., 2021).

Over the past few decades, the use of AI in diverse applications has increased substantially across different sectors and industries (Borges et al., 2021). Global spending on AI was expected to reach around US$ 98 billion in 2023 (Collins et al., 2021). Nevertheless, AI adoption in the construction industry has been moving at a slow pace (Akinosho et al., 2020), with research on AI in this sector mainly confined to developing software models for a specific subset of construction works. For this they have been using knowledge-based expert systems that have failed to gain wide acceptance on account of their inherent deficiencies.

Sinesilassie et al. (2019) stated that, "A construction project is considered as successful when it is completed in time, without cost overruns, and within the specified quality parameters". So-called "success factors" are interconnected performance factors that contribute to project success, as determined by the project management system that provides the tools to coordinate the technologies and people needed to complete a project to maximise chances of project success (Olugboyega et al., 2020). They form the basis for organizations to achieve success on projects (Nguyen et. al., 2020).

Though extensive research has explored the role of AI in software projects, the role of artificial intelligence as a critical success factor for construction projects has not been explored in project management literature. This omission spurs the current work that aims to identify whether AI is becoming a potential critical success factor for construction project success, that is, used in construction projects to increase project performance and efficiency. Thus, in this paper we address the following research question: *Can AI help complete construction projects within budget, on-schedule, and according to specifications thereby increasing the chances of project success?*

The construction industry lags behind many other industries in implementing AI solutions and remains severely under-digitized. AI may help in developing collaborative business models that can alter the current business environment, thereby improving performance and efficiency in the construction industry across the value chain from production of building materials to design, planning, execution, and maintenance (Akinosho et al., 2020). The huge benefits that can be obtained from applying AI in construction projects, therefore, necessitates understanding its role as a success factor for construction project success.

Very few studies have taken a practitioner's viewpoint that could provide valuable insights to construction project professionals in their daily activities (Townsend & Gershon, 2020). This study explores the perceptions of senior project practitioners about AI's role as a success factor in construction projects. To the best of our knowledge this is the first study in project management literature that identifies this gap and attempts to fill it.

The rest of the paper is structured as follows: The next section provides a literature review. Following that, the research approach and results constitute the next two sections. The next two sections then contain discussion and conclusions, including limitations of the research and directions for future research.

Literature Review

Artificial Intelligence

The roots of AI can be traced back to the seminal work of Vannevar Bush who proposed a system called memex, a machine proposed to be an enlarged intimate supplement to a person's memory (Bush, 2021), and Alan Turing (1950) who gave the idea of thinking machines that can imitate human beings. The term "artificial intelligence" was first used by John McCarthy in his Dartmouth Summer Research Project proposal in 1955 (McCarthy et al., 2006; Epstein, 2015). Early systems like ELIZA and General Problem Solver were developed in the 1960s based on the assumption that human intelligence can be formalized (Haenlein & Kaplan, 2019). Since then, we have come a long way from simple machine learning with collecting and processing of data to the present-day use of AI as a multidisciplinary field with intelligent thinking machines performing complex functions and procedures without human involvement. However, many believe that AI has failed to meet its high expectations (Muthukrishnan et al., 2020). Artificial neural networks, machine learning, genetic algorithms, fuzzy logic/sets, and statistical analysis form the basis of most applications under the label of AI, whereas topics like robotics technology, modular construction, energy, 3D printing, life cycle cost, and LCA have not been sufficiently researched (Darko, et al., 2020).

Pan and Zhang (2021) performed a scientometric and qualitative analysis on the current state of AI adoption in the context of construction, engineering, and management (CEM) inside the architecture, engineering, and construction (AEC) industry, and reviewed 4,473 journal articles published from 1997 to 2020. They found that various AI techniques have led to more reliable, time-saving, and cost-effective processes in CEM, under great uncertainty and intensive data that reveals the potential value of AI in supporting and improving CEM. Shukla et al. (2019) performed a bibliometric analysis of publications in the journal *Engineering Applications of Artificial Intelligence* (EAAI) using data from Web of Science (WoS) for the period 1988–2018. Darko et al. (2020) made a comprehensive

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scientometric study that analyzed 41,287 relevant publications for the period from 1974 to 2019, which assessed the state-of-the-art of research on AI in the AEC industry. A common thread linking these three most recent and comprehensive reviews are the concepts of "expert system," "fuzzy logic," "machine learning," and "optimization"/ "algorithm" as broad engineering applications of AI.

In the construction industry, research on AI has mainly been confined to developing software models for a specific subset of construction works using knowledge based expert systems (Ayhan & Tokdemir, 2019). Some of the researchers view AI techniques as suitable for solving complex real-world construction problems under uncertain environments (Tiruneh et al., 2020), while others view AI based systems/models as incapable of addressing real-world problems (Darko et al., 2020). Raisch and Krakowski (2021) argued for a substantial change in the way AI research in general is currently conducted to provide practice with sound advice.

Critical success factors

Critical success factors are levers that can address project success (Costantino et al., 2015) and directly increase the likelihood of attaining success (Maghsoodi & Khalilzadeh, 2017). Understanding the impact of critical success factors on project performance is considered a means of improving their efficiency and effectiveness (Sinesilassie et al., 2019). Daniel first discussed the concept of "success factors" in the 1960s (Leidecker & Bruno, 1984). Rockart, based on Daniel's conceptualization, has introduced a critical success factors (CSFs) approach and de ned CSFs as, "those few key areas of activity in which favorable results are absolutely necessary for a particular manager to reach his or her goals" (Rockart, 1982).

Several works in the construction context have recognized factors that support completing construction projects successfully, especially the factors that have a greater effect on project success than others (Altarawneh & Samadi, 2019). Cheng et al., (2021) considered "technology" as one factor influencing productivity at construction sites. Kang et al. (2013) evidenced that use of IT in construction manifests itself through improvement in work processes that can lead to increased project performance. Many researchers have proposed AI systems to support time-cost-quality trade-off analyses in project management and performance (Elfaki et al., 2014; Costantino et al., 2015). Pan and Zhang (2021) believed that AI can substantially benefit in automation, risk mitigation, and optimization, thereby making construction projects run more smoothly and efficiently. Klashanov (2016) opined that in construction, actively applying ICT helps in selecting economically feasible methods of management based on reliably grounded AI methods. Webber et al. (2019) suggested that AI tools can empower team leaders in doing team analysis and identifying improvement areas. Dam et al. (2019) claimed that AI technologies help in increasing success in agile (software) projects. Various lists of critical success factors for construction project success have been documented by numerous previous studies. However, *AI is not included as a CSF in any of the previous studies reviewed* (see Appendix A, Table I).

Methods

According to Cresswell (2013) qualitative approach is "appropriate to use to study a research problem when the problem needs to be explored; when a complex, detailed understanding is needed". This methodology is characterized by generating understanding, rather than testing (Corbin & Strauss, 2008). It "emphasizes words rather than quantification in the collection and analysis of data" (Bryman, 2012). This methodology is often adapted to understand a phenomenon about which little is known. Interviews, as a qualitative approach instrument, can be used for exploring new phenomena and for capturing individual understandings of meanings and processes (Given, 2008).

Interviews

Interviews are seen as a research strategy or technique for theory generation or theoretical framework generation. Qualitative interviews have the potential to generate insights and concepts and expand our understanding (Knight & Ruddock, 2008). Semi-structured interviews are employed to "learn the respondent's viewpoint regarding situations relevant to the broader research problem" (Blumberg et al., 2008 cited in Davis, 2017), provide rich data collection, allow for clarifications and expansion upon questions and answers during the interview (Davis, 2017). We chose to conduct semi-structured interviews to allow for identifying additional themes during discussions and to provide an opportunity for elaboration by interviewees. Various authors have recommended a different number of interviews to arrive at saturation in qualitative studies. Creswell (1998) recommended between five and twenty-five interviews, while Kuzel (1992) recommended six to

Table 1. Respondent's profile, geography, and projects handled

S. No.	Item	Respondent 1 (PD)	Respondent 2 (PM)	Respondent 3 (PD)
1	**Qualification**	Master's in science	Degree in Engineering	Masters in Geology
2	**Total experience**	15 years	15 years	33 years
3	**Present project**			
3.1	Project type	Airport	Nuclear	Road, Building
3.2	Project location	Saudi Arabia	France	Algeria
3.3	Role in project	Project Director	Project Manager	Project Director
3.4	Project cost (tentative)	Project 1-Nine Billion US dollar (construction cost) Project 2 – 100-200 Million US dollar (construction cost)	35 billion euro (construction cost)	Project 1-110 million euro (consulting fee) Project 2-40 million euro (consulting fee) Project 3-8 million euro (consulting fee)
3.5	Present progress	Construction stage	Construction stage	Project 1-Closure stage Project 2-Ongoing project 3-Closure stage
S. No.	**Item**	**Respondent 4 (PD)**	**Respondent 5 (PM)**	**Respondent 6 (OM)**
1	**Qualification**	Graduate Engineer, MBA	Master's in engineering	High School
2	**Total experience**	23 years	11 Years	15 years
3	**Present project**			
3.1	Project type	Mining	Light rail	Road (O&M)
3.2	Project location	Africa	France	UK
3.3	Role in project	Project Director	Project Manager	O&M Manager
3.4	Project cost (tentative)	Two billion Euro (construction cost)	80 million euro (construction cost)	300-million-pound consulting fee for a 30-year O&M contract
3.5	Present progress	Recently completed	Construction stage	Operation and maintenance
S. No.	**Item**	**Respondent 7 (DP)**	**Respondent 8 (PM)**	**Respondent 9 (PM)**
1	**Qualification**	Master's in research, master's in engineering	Engineering, Business Administration	Graduate Engineer
2	**Total Experience**	15 years	14 Years	25 years
3	**Present project**			
3.1	Project Type	Road	Green Network	Road
3.2	Project location	French island	France	India
3.3	Role in project	Deputy Project Director	Project Manager	Project Manager
3.4	Project cost (tentative)	Five billion euro – construction cost	60 million euro (construction cost)	Five+ billion INR (construction cost)
3.5	Present progress	Construction stage	Construction stage	Recently completed

Table 2. Themes and sub-themes

Theme	Sub-Themes
Theme 1 Artificial Intelligence (AI)	(1a) Project professionals' perceptions of AI
	(1b) AI vs. information technology
	(1c) AI vs. advanced project management software
Theme 2 AI and Construction project success	(2a) AI's perceived help to achieve greater project success
	(2b) AI's present use in construction projects
	(2c) AI's perceived timeline to become reality on construction projects
	(2d) AI's perceived impact on construction projects in the future.
Theme 3 AI vs. Project manager	(3a) AI perceived help to project managers
	(3b) Decision power/dominance

eight interviews (cited in Guest et al., 2006). Galvin (2015) found 8 to 17 interviews as the most common range, while Hennink et al. (2016) found that code saturation was reached after nine interviews.

The interviewees were selected on a convenience basis and included highly experienced project practitioners from the global community with expertise in project management, who have work experience on large construction projects and are engaging with state-of-the-art technology and AI integrated project management software like BIM, ERP etc. (Eber, 2020; Aktürk, 2021; Goundar et al., 2021). We conducted a total of nine face-to-face interviews between March 2019 and June 2019. Eight of the interviews took place in France and were video recorded, while one interview took place in India and was audio recorded. All nine interviews were then manually transcribed. Data were coded manually and analyzed using content analysis.

Data analysis related issues

Davis (2017) suggested replacing the terms "validity" with "truth value" and "reliability" with "consistency/confirmability" in qualitative studies, since the former are often presented as quantitative measures. We discussed the interview questions with two academic and two industry experts who reviewed and refined them with suggestions. We then developed an interview protocol and finalized it in consultation with the two academic experts. The professionals we interviewed represented seven geographic regions and were handling projects in eight different sectors. Table 1 summarizes the interviewee profiles, including geography, and projects handled.

Interview Results

Respondent profiles

All respondents except one had professional engineering qualifications and were working as a project manager or project director, handling large construction projects with varied teams. Their experience ranged from 10 to 33 years; specifically in project management, the average was 17.9 years. The construction cost of projects handled ranged from 60 million Euro to 35 billion Euro.

Themes and sub-themes

The interviews were manually coded to highlight the trends and differences in the respective interviewee's responses. After the initial coding, similar codes were collated and analysed, then themes were developed. These themes were analyzed to reveal respondents' perceptions about AI and its role as a success factor in construction projects. Table 2 shows the three main themes and related sub-themes identified during the process.

Theme 1: Artificial Intelligence

Project professionals' perception of AI

The key theme explored during the interviews was perceptions about AI by senior projects managers. We found varied and diverse perceptions of AI among the project professionals with some viewing it as an "intelligent system," some as a "processing tool," and others as a "prediction and data analysis" tool that

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outputs meaningful results from big data. Some respondents perceived AI as an intelligent system capable of analysing and making decisions like humans, while others disagree with that. Some respondents saw it as a processing tool or system that can help with specific activities to answer basic questions when asked in certain ways. Still others perceived it as a tool used for predicting and analysing big data and predicting situations, that it is "intelligent" with limited capabilities (See Appendix A, Table II).

AI vs. information technology
Two opposite views were found regarding AI as information technology (IT) with a majority of the respondents perceiving AI as different from IT, while a minority of others perceive AI and IT as the same thing, with only a difference of "level". Seven interviewees believed that AI differs from IT. They believe that AI uses IT as input, learns and improves by itself, can reason, interpret, make decisions, and reach conclusions. One unique respondent viewed AI and IT as the same thing, saying that both go hand-in-hand. He believed there is a level difference between AI and IT, meaning that AI is at a higher in level than IT, however, he accepted that AI cannot think for itself, since it is not self-aware.

AI vs. advanced project management software
Two opposite views were found about AI as an advanced project management software. Most respondents perceived AI being superior to advanced project management software, while minority others see AI and IT as the same. Seven interviewees saw AI as superior to advanced project management software like ERP, Civil-3D, or SAP, in that software can only simulate based on input data and cannot propose, whereas AI can propose different scenarios and offer a best option. One respondent viewed AI and IT as software programs.

Theme 2: Artificial Intelligence and construction project success

AI's perceived help to achieve greater project success
The opinions received about AI's perceived help to achieve greater project success were divided, overlapped, and varied from help in design, analysis, data processing, and with technical aspects only, and of no help in actual construction work. Five respondents opined that AI could help in designing, analysing, and predicting future suitability projections of a facility being constructed, thereby re-aligning investment strategies and phasing. Four respondents viewed it as a tool for data processing, quick designs, risk evaluation or quantification, visualization, and planning. Five respondents viewed it as primarily helpful in planning and technical aspects by way of cutting down the time required. One respondent opined that AI will in fact increase efforts through extra time required to feed data to the system and review outputs. However, most respondents did not see AI as suitable during actual construction works and remained skeptical about AI being much help in construction: "…maybe, but I am not convinced."; "In a theoretical way it could work"; "It can or maybe it's like it can…"; "…maybe it, but in the sense…" (see Appendix A, Table III).

AI's present use in construction projects
None of the respondents said they were using any sort of AI technology in their present construction projects. One respondent believed that though direct AI was not being used for their construction projects, sometimes software and tools based on AI were used for traffic analysis. He refused, however, to consider project management software (such as ERP, SAP, and Civil 3D) as an example of AI.

AI's perceived timeline to become reality on construction projects in future
All respondents expressed certainty that AI is going to become a reality in construction projects in the future, though opinions regarding capabilities and timeframes for its emergence varied among them. Most of the respondents were of the view that AI may become a reality on construction projects within the next 7-20 years. One respondent believed that the problem with AI would not be technological, but rather the need to convince project managers to adopt it. One respondent viewed BIM software use as an intermediate stage to AI. One respondent remained skeptical about AI's capabilities, suggesting that AI can learn only within the parameters of programming, and that would mean somebody focusing on AI instead of on a project, at least until AI becomes "self-aware", which was considered as a point to worry about.

AI's perceived impact on future construction projects
Responses from respondents were mixed with most foreseeing a very limited role for AI in future construction projects and that it would be limited to the design, feasibility studies, and structured pre-construction phases. They perceived little benefit during the construction phase where humans are always facing surprises and must adapt to unknown situations, find

solutions quickly, and in the right way. Most respondents were unsure or doubtful about the potential advantages of using AI in the construction phase: "I am not sure how"; "it can happen, it may happen"; "maybe I am wrong, but I think, no". Respondents were worried about losing employment to AI, as well as control over application of AI in construction projects.

Three respondents saw its use in the preconstruction design phase only, with not much use in the construction phase, as they doubted the ability of AI to develop soft skills and manage human relations. One respondent was apprehensive about AI having sufficient flexibility and agility to adopt a solution quickly and in a right way. Two respondents believed that eventually, like in other fields, AI will eventually find its place in complex construction projects and may help project managers dealing with multiple parameters by proposing quicker solutions. One respondent, in contrast, did not perceive any benefit from AI in future construction projects unless programs can think and make decisions on their own as a human would. This respondent was of the view that AI would be forced to make decisions that would have already been known to a person, and made a strong pitch for human analytical skills to assess situations and arrive at conclusions that AI would not be able to: "So, if you went to look at a structure that was damaged and as a … human you would look at it and would make a judgement on what type of repair [it needs], what was damaged, [and] so on and so forth. And AI could never do that".

Theme 3: Artificial Intelligence vs. project manager

AI as perceived help for project managers
The respondents were quite unanimous in their perception about AI currently being of very limited help to project managers during actual construction work. They perceived AI as a support assistant to the project manager for effective decision making. They viewed AI as being more useful during initial designs and simulations for optimizing resources and effective decision making. AI was perceived help in providing quick, well-formatted information and managing some regular tasks with first-hand checking. They opined that AI may be useful for processing data and proposing the most accurate option for one's project, thereby aiding the project manager's decision-making capacity. They did not perceive AI as a tool for the construction phase, in contrast to thinking of AI as "fully autonomous construction of useful real-world structures" in the future, as predicted by researchers like Melenbrink et al. (2020). The construction project manager was seen as having the final say in validation and decision-making.

The major AI drawbacks identified by the respondents were the lack of soft skills (which humans possess), lack of intelligence to interpret things in various ways like human beings, and human relationship capabilities: "[B]ut the solution is never white or black; sometimes its white, sometimes its black, but often it's a compromise between you [and] the client", when it comes to managing projects.

Who will have decision-making power or dominance?
The respondents believed that project managers will continue to have the final decision power in the foreseeable future. However, the opinion on dominance was not held by one respondent who believed that AI would dominate and project managers "will just need to follow" the AI's recommendations. One respondent believed that until or unless AI can "argue back", there would not be any problem, but saw a big problem in the prospect of AI becoming self-aware in the future. All respondents except one agreed that final decision-making power should lie with the project manager, with the caveat that "as a project manager, you may take a decision which may not appear logical but for some political issue, economical issue, etc. you may choose in a different way" (see Appendix A, Table IV).

The interviews highlighted important perceptions about the roles and capabilities of AI in the minds of practitioner and emphasized the need to explore AI as a success factor for construction projects. The issues identified in the interviews were compared to those in the reviewed studies. The findings are summarized in the Discussion and Conclusions sections.

Discussion

The perceptions of construction project professionals reflect a contrast to the published literature about the current day success stories of AI-automated construction processes being used on construction projects. Table 3 shows the perceptual mapping of the identified themes and sub-themes within the published literature.

Artificial Intelligence
Perceptions from respondents who regarded AI as a processing tool or system contrasted with what has been

Table 3. Perceptual mapping of AI in construction project

Theme	Sub-themes	Scientific Contribution
Theme 1 Artificial Intelligence	(1a) Perception of AI	Haefner et al., 2021; Haenlein & Kaplan, 2019
	(1b) AI as information technology	Pan & Zhang, 2021
	(1c) AI as advanced project management software	Aktürk, 2021; Goundar et al., 2021; Sacks et al., 2020
Theme 2 AI and construction project success	(2a) AI's perceived help to achieve greater project success	Pan & Zhang, 2021
	(2b) AI's present use on construction projects	Pan & Zhang, 2021
	(2c) AI's perceived timeline to become reality on construction projects	Haenlein & Kaplan, 2019;
	(2d) AI's perceived impact on construction projects in the future	Tiruneh et al., 2020
Theme 3 AI vs. project manager	(3a) AI's perceived help for project managers	Haefner et al., 2020
	(3b) Who has decision-making power and dominance?	Haefner et al., 2020

reported in previous studies about the success stories of AI. Respondent views of AI as an intelligent system somewhat aligned with the researchers' views of AI being a science of inventing intelligent machines and computer systems (Kumar et al., 2019; Darko, et al., 2020); a system capable of correctly interpreting and learning from external data (Kolbjørnsrud et al., 2017; Haenlein & Kaplan, 2019). However, practitioner respondents did not perceive AI as capable of accessing field situations during the construction progress or of making decisions like project managers. This stands in contrast to previous studies by researchers like Hamet and Tremblay (2017), Haefner et al. (2021), and Pan and Zhang (2021). The respondent perceptions of AI as being superior to project management software was in contrast to the published literature that claims AI as an integrated part of PMS software like ERP and others (Aktürk, 2021; Goundar et al., 2021).

AI and construction project success

The findings from the interviews differ regarding the suitability of AI during the construction project execution phase. The present state of use of AI, the timeline for AI to become a realty on construction projects, and the perception of a limited and only supportive role of AI in future construction project contrasted with the published literature. The published literature that have predicted since the 1950s that AI would reach intelligence behaviour *indistinguishable from humans* within a "few years" (Haenlein & Kaplan, 2019; Şerban & Todericiu, 2020; Borges et al., 2021) were not reflected in the current study. Pan and Zhang (2021) opined that various AI approaches can achieve three major functions that are beneficial to CEM in terms of automation, risk mitigation, high efficiency, digitalization, and computer vision, including (i) Modeling and pattern detection, (ii) Prediction, and (iii) Optimization. However, respondents' opinions also contrasted with this.

The perception about AI being helpful in design and analysis, data processing, planning and risk evaluation was in line with previous studies (Ayhan & Tokdemir, 2019; Zheng et al., 2020; Pan & Zhang, 2021). As was the concern about AI potentially becoming "self-aware" in the future, along with fear of losing jobs (Epstein, 2015; Kaplan & Haenlein, 2019; Kumar et al., 2019; Borges et al., 2021; Loureiro et al., 2021). The concerns regarding ethical, legal, and philosophical challenges associated with AI have been raised in many previous studies (Haenlein & Kaplan, 2019; Asatiani, et al., 2021; Du & Xie, 2021), including by the noted scientist Stephen Hawking, who stated: "Success in creating effective AI, could be the biggest event in the history of our civilization. Or the worst. We just don't know" (cited in Girasa, 2020).

It thus appears that several apprehensions need to be removed from the minds of project professionals if the benefits of AI are to be reaped. Concerns about AI's flexibility and agility to adopt solutions quickly and in the right way were in line with Sacks et al. (2020). They found that basic BIM functions took 25 years to reach the market, none of the robotic machines made for construction achieved the revolutionary change they were thought to, and automation in construction has proved to be a frustratingly difficult goal when it comes to implementation.

Artificial intelligence vs. project manager

The finding that AI lacks soft skills and human intelligence to interpret things in different ways was in line with Epstein (2015) and Sinz et al. (2019). They found that the "skills" of artificially intelligent computers are even below that of a one-year-old child when it comes to perception and mobility. The belief that project managers will have final decision-making power was also in line with the opinion of Haefner et al. (2021) that the "judgement of managers may be difficult to replace". Respondents' opinions about AI being of limited help to professionals during construction projects aligns with the findings of Sacks et al. (2020) about automated project performance monitor and control systems encountering technical and conceptual barriers to provide real-time feedback to project managers. Likewise, the non-reliability of information provided thereby requires manual review and intervention that often invalidate the benefits of automation.

Conclusions

In this paper we addressed the following research question: *Can AI help complete construction projects within budget, on-schedule, and according to specifications thereby increasing the chances of project success?* In attempting to understand the inherent ambiguity, complexities, and dynamics of most large construction projects that bring in scheduling disruptions, cost overruns, and compromised conditions, this paper has observed the need for state of art technologies to protect construction projects from negative impacts. While we attempted to identify whether AI is a potential candidate as a critical success factor for construction project success, this paper's findings suggest that the perceptions of project practitioners about AI's suitability in field construction works differ from published studies. Likewise, the role of AI as a critical success factor in construction projects is yet to be fully explored.

Interview data that we collected show that construction practitioners' views are different from research findings regarding AI capabilities and uses. Project managers are aware about the advantages and capabilities of AI, perceiving AI as a tool or system that can predict and analyse, learn and make decisions at its own, or even potentially become self-aware, in contrast with information technology and advanced project management software. They perceive that AI is still in a very primitive stage and has a very restricted role during the execution phase of construction projects, which is primarily limited to design calculations and as support for project managers in completing basic repetitive tasks. The major drawbacks of AI cited by our interview respondents were its lack of soft skills, human-like intelligence to interpret things in various ways, human relationship capabilities, and the way human beings manage projects. Findings from these interviews highlighted the need to connect future research with the role of AI as a critical success factor for construction projects to exploit the full potential and advantages of AI in the construction industry. AI has already started affecting the entire value chain system of companies and is transforming industries in a fundamental manner. For project practitioners, this research provides a real-world example of senior project manager experiences. Given the good potential for AI uses on construction projects, we believe that project practitioners may increasingly opt to use AI more and more in executing their routine work to increase project performance and efficiency, thereby increasing the chances of project success.

Further, though prior literature has discussed CSFs in great detail, this study has tried to build a space for itself in the discourse. It provided insights for further research on AI as a CSF for scholars in project management, thereby complementing the existing body of work around the benefits of AI that contributes to success through extending CSFs.

Limitations and directions for future research

The major limitations of this study include the small sample size. This necessitates investigating the views of other stakeholders directly involved on the construction projects as well. We propose more in-depth interviews and surveys should be conducted with a wider audience in the construction industry to ensure comparable results. This would increase the credibility of this study and to allow for confirmation of whether this study's findings are similar across a larger sample of stakeholders.

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Appendix A

Table 1. Critical Success Factors identified in previous studies

CSF Dimensions	Scale item	Scientific Contribution
Human factors	Project manager's competency / Project team competency	Sanvido et al., 1992; Belassi & Tukel, 1996; Chua et al.1999; Chan et al., 2004; Nguyen et al., 2004; Fortune & White, 2006; Iyer & Jha, 2006; Yu et al., 2006; Toor & Ogunlana, 2009; Kog & Loh, 2012; Tabish & Jha, 2012; Gudienė et al., 2013a; Hwang & Lim, 2013; Davis, 2014; Ihuah et al., 2014; Rolstades et al., 2014; Taherdoost & Keshvarzsaleh, 2016; Maghsoodi & Khalilzadeh, 2017; Misic & Radujkovic 2017; Tsiga et al., 2017; Asgari et al., 2018; Ghanbaripour et. al., 2018; Mavi & Standing, 2018; Sinesilassie et. al., 2018; Altarawneh & Samadi, 2019; Negash et al., 2020
	Project manager's leadership	Fortune & White, 2006; Hyväri, 2006; Muller & Turner, 2007; Kaulio, 2008; Qureshi et al., 2009; Muller & Turner, 2010; Kandelousi et al., 2011; Walker & Walker, 2011; Ahadzie et al., 2014; Cserháti & Szabó, 2014; Ihuah et al., 2014; Medina & Medina, 2014; Lloyd et al., 2015; Andersen, 2016; Ghanbaripour et. al., 2018; Altarawneh & Samadi, 2019; Ahmed et al., 2020
	Project participants commitments in meeting the project goal	Sanvido et al., 1992; Belassi & Tukel, 1996; Chan et al., 2001; Nguyen et al., 2004; Iyer & Jha, 2006; Yu et al.,2006; Jha & Iyer, 2007; Tabish & Jha, 2012; Hwang & Lim, 2013; Cserháti & Szabó, 2014; Ghanbaripour et. al., 2018; Altarawneh & Samadi, 2019; Jitpaiboon et. al., 2019
	Trouble shooting	Pinto & Slevin, 1987; Toor & Ogunlana, 2009; Gudienė et al., 2013; Ihuah et al., 2014; Altarawneh & Samadi, 2019
	Good coordination between project participants	Belassi & Tukel, 1996; Chan et al., 2004; Jha & Iyer, 2007; Tabish & Jha, 2012; Gudienė et al., 2013; Cserháti & Szabó, 2014; Ihuah et al., 2014; Asgari et. al., 2018; Ghanbaripour et. al., 2018; Sinesilassie et. al., 2018; Altarawneh & Samadi, 2019; Negash et al., 2020
	Top management support	Nguyen et al., 1992; Belassi & Tukel, 1996; Iyer & Jha, 2006; Kumar & Iyer, 2007; Tabish & Jha, 2012; Cserháti & Szabó, 2014; Gudienė et al., 2014; Ihuah et al., 2014; Asgari et. al., 2018; Ghanbaripour et. al., 2018; Sinesilassie et. al., 2018; Altarawneh & Samadi, 2019; Jitpaiboon et. al., 2019; Negash et al., 2020
	Decision making effectiveness	Fortune & White, 2006; Iyer & Jha, 2007; Thi & Swierczek, 2010; Gudienė et al., 2014; Altarawneh & Samadi, 2019; Jitpaiboon et. al., 2019
Procurement factors	Comprehensive contract documentation	Sanvido et al., 1992; Chua et al., 1999; Nguyen et al., 2004; Toor & Ogunlana, 2009; Alzahrani & Emsley 2013; Cserháti & Szabó, 2014; Maghsoodi & Khalilzadeh, 2017; Ghanbaripour et. al., 2018; Altarawneh & Samadi, 2019
	Competitive procurement process	Chan et al., 2004; Li et al.; 2005; Cheung et al., 2012; Altarawneh & Samadi, 2019; Negash et al., 2020
	Transparency in procurement process	Chan et al., 2004; Li et al., 2005; Gudienė et al., 2013a; 2013b; Altarawneh & Samadi, 2019; Negash et al., 2020

Appendix A

Table 1. Critical Success Factors identified in previous studies (cont'd)

	Appropriate risk allocation and risk sharing	Li et al., 2005; Kog & Loh, 2012; Gudienė et al., 2013b; Hwang & Lim, 2013; Ihuah et al., 2014; Maghsoodi & Khalilzadeh, 2017; Altarawneh & Samadi, 2019
	Accurate and reliable estimates of project costs	Maghsoodi & Khalilzadeh, 2017
	Awarding bids to the right designer/contractor	Nguyen et al., 2004; Toor & Ogunlana, 2008; Maghsoodi & Khalilzadeh, 2017; Sinesilassie et. al., 2018
Project management factors	Development of a good project plan	Chan et al., 2004; Toor & Ogunlana, 2009; Gudienė et al., 2013a; Ihuah et al., 2014; Maghsoodi & Khalilzadeh, 2017; Altarawneh & Samadi, 2019
	Adequate use of communication among project participant	Sanvido et al., 1992; Nguyen et al., 2004; Yu et al., 2006; Jha & Iyer, 2007; Toor & Ogunlana, 2008; Tabish & Jha, 2012; Cserháti & Szabo, 2014; Ghanbaripour et. al., 2018; Sinesilassie et. al., 2018; Altarawneh & Samadi, 2019
	Clarity of project goal to the project team	Ashley et al., 1987; Pinto & Slevin, 1987; Chan et al., 2004; Yu et al., 2006; Toor & Ogunlana, 2008; Cserháti & Szabó, 2014; Ghanbaripour et. al., 2018; Altarawneh & Samadi, 2019; Jitpaiboon et. al., 2019
	Effective project monitoring and control system	Ashley et al., 1987; Pinto & Slevin, 1987; Chan et al., 2004; Iyer & Jha, 2006; Jha & Iyer, 2007; Toor & Ogunlana, 2008; Tabish & Jha, 2011; Hwang & Lim, 2013; Gudienė et al., 2013a; Cserháti & Szabó, 2014; Ihuah et al., 2014; Maghsoodi & Khalilzadeh, 2017; Ghanbaripour et. al., 2018; Sinesilassie et. al., 2018; Altarawneh & Samadi, 2019
	Project team -motivation	Chua et al., 1999; Hwang & Lim, 2012; Inayat et al., 2012; Kog & Loh, 2012; Gudienė et al., 2013b; Hwang & Lim, 2013; Altarawneh & Samadi, 2019
	Effective partnering among project participants	Tabish & Jha, 2011; Sinesilassie et. al., 2018; Negash et al., 2020
	Awareness of and compliance with rules and regulations	Tabish & Jha, 2011
	Flexibility	Shahu et al., 2012; Ghanbaripour et. al., 2018
	Clear objectives and scope	Chan et al., 2001; Nguyen et al., 2004; Yu et al., 2006; Toor & Ogunlana, 2008; Elwakil et al., 2009; Inayat et al., 2012; Kog & Loh, 2012; Hwang & Lim, 2013; Asgari et. al., 2018; Sinesilassie et. al., 2018
	Continuing involvement of stakeholders in the project	Nguyen et al., 2004; Maghsoodi & Khalilzadeh, 2017; Ghanbaripour et. al., 2018; Jitpaiboon et. al., 2019; Negash et al., 2020
	Planning	Inayat et al., 2012; Kog & Loh, 2012; Hwang & Lim, 2013; Ghanbaripour et. al., 2018; Negash et al., 2020
	Supervision level	Ghanbaripour et. al., 2018; Negash et al., 2020

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Appendix A

Table 1. Critical Success Factors identified in previous studies (cont'd)

	Project management practices / methodologies / methods / tools	Jugdev et al., 2013; Joslin & Muller, 2015; Mitra Pedersen, 2016; Radek Doskocil, 2016; Haron et. al., 2017; Ghanbaripour et. al., 2018; Jitpaiboon et. al., 2019
	Client responsiveness	Ghanbaripour et. al., 2018
Project characteristics factors	Project size /	Belassi & Tukel, 1996; Chan et al., 2004; Hyväri, 2006; Ademiluyi, 2010; Inayatet al., 2012; Kog & Loh, 2012; Alzahrani & Emsley, 2013; Gudienė et al., 2013a; Maghsoodi & Khalilzadeh, 2017; Ghanbaripour et. al., 2018; Altarawneh & Samadi, 2019; Negash et al., 2020
	/ Value of a project	
	/ Complexity and uniqueness of project activities	
	/ The type of project (new, existing, maintenance)	
	/ The urgency of project outcome	
	/ Density of a project	
Project environmental factors	Physical environment	Park, 2009; Tabish & Jha, 2012; Gudienė et al., 2013b; Gunduz & Yahya, 2018; Altarawneh & Samadi, 2019
	Natural climates	Chan et al., 2004; Tabish & Jha, 2012; Amade et al., 2015; Gunduz & Yahya, 2018; Altarawneh & Samadi, 2019
	Economic and financial problems like price, local currency value	Pourrostam & Ismail, 2012; Alzara et al., 2016; Durdyev et al., 2017; Maghsoodi & Khalilzadeh, 2017; Ghanbaripour et. al., 2018; Altarawneh & Samadi, 2019; Negash et al., 2020
	Bureaucratic interference	Nguyen et al., 2004; Phua,2004; Altarawneh & Samadi, 2019
	Unexpected geological condition, unexpected prices raise for labor, unexpected prices raise for material	Chan et al., 2004; Tabish & Jha, 2012; Gunduz & Yahya, 2018; Altarawneh & Samadi, 2019
	Late delivery of materials and equipment	Doloi et al., 2011; Akogbe et al., 2013; Aziz & Abdel-Hakam, 2016; Altarawneh & Samadi, 2019
	Shortage of labor	Ugwu & Kumaraswamy, 2007; Ogwueleka, 2011; Alzahrani & Emsley, 2013; Altarawneh & Samadi, 2019
Factors related to project funding	Adequate funding throughout the project	Nguyen et al., 2004; Inayat et al., 2012; Kog & Loh, 2012; Hwang & Lim, 2013; Maghsoodi & Khalilzadeh, 2017; Asgari et. al., 2018; Ghanbaripour et. al., 2018; Negash et al., 2020
	Availability of resources	Nguyen et al., 2004; Maghsoodi & Khalilzadeh, 2017; Sinesilassie et. al., 2018; Negash et al., 2020
Project contract	Proper emphasis on past experience	Sanvido et al., 1992; Nguyen et al., 2004; Alzahrani & Emsley, 2013; Ghanbaripour et. al., 2018
Cultural and socio-demographic factors	National culture, Demographic profile of the respondents	Park, 2009; Al-Tmeemy, Abdul-Rahman, & Harun, 2011; Tripathi & Jha, 2017; Martens et al., 2018; Vijayabanu et al., 2020
Other factors	Organization structure	Belassi & Tukel, 1996

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Appendix A

Table 1. Critical Success Factors identified in previous studies

	Qualified and experienced project management	Maghsoodi & Khalilzadeh, 2017
	Ongoing consultation with the project employer	Maghsoodi & Khalilzadeh, 2017
	Regulations and political or economic and social issues	Maghsoodi & Khalilzadeh, 2017; Negash et al., 2020
	Pre-project planning and clarity in scope	Tabish & Jha, 2011; Sinesilassie et. al., 2018; Jitpaiboon et. al., 2019
	Up to date technology utilization / Advanced technologies / Use of IT tools	Chan et al., 2004; Nguyen et al., 2004; Toor & Ogunlana, 2008; Elwakil et al., 2009; Negash et al., 2020
	Owner's competence	Iyer & Jha, 2006; Asgari et. al., 2018
	Favourable working conditions	Iyer & Jha, 2006; Ghanbaripour et. al., 2018; Negash et al., 2020
	Contractor's company characteristics, technical and professional ability / competence & experience	Alzahrani & Emsley, 2013; Asgari et. al., 2018; Ghanbaripour et. al., 2018; Negash et al., 2020
	Decision making effectiveness	Fortune & White, 2006; Iyer & Jha, 2007; Thi & Swierczek, 2010; Gudienė et al., 2014; Altarawneh & Samadi, 2019; Jitpaiboon et. al., 2019
	Design expertise	Chan et al., 2001; Ghanbaripour et. al., 2018; Negash et al., 2020
	Education and training	Negash et al., 2020
	Formal dispute resolution process	Toor & Ogunlana, 2008; Inayat et al., 2012; Kog & Loh, 2012
	Legal environment / Legal expertise	Ghanbaripour et. al., 2018; Negash et al., 2020
	Material and equipments	Negash et al., 2020
	Mutual trust among project stakeholders	Ghanbaripour et. al., 2018
	No major changes in the scope of work during construction	Sinesilassie et. al., 2018
	Project cultural fit	Ghanbaripour et. al., 2018
	Regular quality control and quality assurance systems	Ghanbaripour et. al., 2018; Sinesilassie et. al., 2018
	Skilled workers	Ghanbaripour et. al., 2018; Negash et al., 2020

Note: Based on the scale by Altarawneh and Samadi, 2019 along with the authors' compliation.