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The use of AI algorithms in architecture, engineering and construction: A tool for crisis prevention? The uncertainty perspective

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Abstract

Within the Architecture, engineering and construction (AEC) sector we see movements toward greater use of industrial robots, machine learning, algorithms, and other artificial intelligence (AI) tools. Yet, the AEC industry, despite being one of the largest fields on a global scale, is known for being the slowest to digitalize and innovate. Factors such as unrecognizing the value of digitalization by the decision-makers and making safety-related decisions under high levels of uncertainty, appear to be critical in preventing successful large-scale digitalization. This situation raises multiple questions from a risk science perspective. How, among other things, might the expansion of AI and more specifically AI algorithms usage in the AEC field affect uncertainties, and could AI be considered a tool for preventing crises? To obtain responses to these questions, we conducted 21 semi-structured, in-depth interviews with AEC employees who are currently using AI and AI algorithms or will soon be doing so in their everyday work. Our findings show potential for wider use within the AEC field, subject to overcoming knowledge gaps. Moreover, although having the potential to reduce some uncertainties, the increased use of AI and AI algorithms appears to be introducing an entirely new set of uncertainties. As a result, although AI may effectively prevent certain crises and be regarded as crisis prevention tool, its inadequate implementation could potentially create new risks.

Keywords: AEC, AI, algorithm, crisis, uncertainty

1. Introduction

The Architecture, Engineering and Construction (AEC) sector has proven a great potential to widely employ robotics and Artificial Intelligence (AI) in the past twenty years (Emaminejad & Akhavian. 2022). For instance, industrial robots are used as one option for the deconstruction site automation (Lee & Brell-Cokcan, 2023). Machine learning has been implemented to automate the building design process, using Building Information Modelling (BIM) data, collected from different projects, and save time on the design process compared to traditional approaches (Zabin et al., 2022). Recourse to AI, and more specifically Big Data technology in the construction sector offers potential in areas such as resource and waste optimization, value added services, facility management, energy management & analytics (Bilal et al., 2016). In addition, Pan & Zhang (2021) also consider automation, risk mitigation, high efficiency, digitalization and computer vision as the main pluses of using AI in construction and engineering.

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Many of the AI current and potential applications in the AEC field are based on AI supported algorithms. Different AI algorithm supported robots can be of aid in relation to site inspections, assembly and material handling (Goly, 2023). Drones are used in multiple phases of construction projects, from the stage of land purchase to the post construction stage of the project with almost no risk and while providing real-time information (Mahajan, 2021). Data-driven mechanisms to empower construction machinery with intelligence rely on industrial data resources and AI algorithms, which carry potential in intelligent construction machinery (Zheng et al., 2023). Scheduling and optimization algorithms could be deployed to derive new strategies to address possible issues arising during an onsite construction project (Turner et al., 2021), and the rule checking algorithms for detecting required prevention methods for slab edge (Zhang et al., 2015). Nevertheless, it would be possible to use transportation route optimisation algorithms for project planning (Blanco et al., 2018).

The future of the AEC industry is influenced by two major developments (The World Economic Forum, 2016):

- Buildings are responsible for 30% of global greenhouse gas emissions, which is considered a call for urgent action. The United Kingdom government, for instance, has a 2025 target for 50% reduction in greenhouse gas emissions in the country's-built environment.
- The world's population is growing at a pace of 200 000 people per day. This, combined with lifestyle changes and expectations, suggests that the need for housing, transportation and other types of infrastructure will continue to increase significantly.

Therefore, it should come at no surprise that calls for digitalization are coming from many different corners. The Construction 2025 Industrial strategy report published in the UK in 2013 offers one such example. The report addressed technology advancements, use of BIM, as well as research and innovation needs (HM Government, 2013). On the EU level, the European Commission (2021) reports that in most EU Member states (16 out of 27), policies are in place to target the digitalisation of the construction sector. Many national governments have BIM requirements in place as part of their public procurement process.

Yet, while AEC is one of the largest economic sectors in the world, it is one of the slowest to digitize and innovate (Abioye et al., 2021; Blanco et al., 2018; McKinsey & Co., 2020; The World Economic Forum, 2016). As it seems decision-makers in the AEC field lack knowledge about the implementation of digitalization to generate value (Lavikka et al., 2018). It does not help that the AEC industry usually comprises small businesses (82.3%) which are known for being late technology adopters (Emaminejad & Akhavian, 2022). Several authors also identified challenges to the digitalization of the AEC sector. The main issues include data security, privacy, protection (big data) (Bilal et al., 2016), a lack of common data standards, data security and ownership (digital twins) (Shahzad et al., 2022).

When discussing the adoption of AI technology, a key element for the successful integration into organizations is the workers' "trust in AI technology" (Glikson & Woolley, 2020). Many times, however, this precondition is not met (Ibid,). Many organizations face the challenge of algorithmic aversion, in which people tend to place more trust into human interventions than algorithmic performance even when seeing an algorithm outperforming a counterpart human (Dietvorst et al., 2014). Employing AI algorithms demands accurate data for training, whereas collecting large datasets can be very costly and time-consuming for many construction companies (Regona et al., 2022). Moreover, only a limited number of people can interpret the data, leading to limited economies of scale, thus hindering digitalization and innovation (Regona et al., 2022). Finally, there is a question about whether the wider use of AI in the field could lead to different types of crises, such as unemployment resulting from automatization(Ford, 2013; Hughes, 2014).

2. Could AI Algorithms be seen as a Crisis Prevention Tool?

A very large share of construction works, up-stream or downstream of groundbreaking, involves making safety-related decisions under uncertainty (Tixier et al., 2017). Inaccurate location-awareness, blind spots, and unexpected environment disturbances are only a part of the many uncertainties present in the construction field operations (Zheng et al., 2023). In the context of AI use in AEC we witness more calls for improved risk analysis, such as in machine learning applications to BIM (Zabin et al., 2022). Therefore, it is of great importance to provide construction practitioners with tools to mitigate the adverse consequences of uncertainty on their safety-related decisions (Tixier et al., 2017).

According to risk research, there is a number of obstacles when implementing new technologies that could hinder the idea of employing AI algorithms as crisis prevention tools. Early on, Slovic (1987a) discussed what appears to be public's concerns towards risky technologies, and highlighted the importance of education in that context which would lead to a change in risk perceptions. We also witness great technological advancements, but despite these advancements on the technological side, too little progress has been achieved in improving the understanding of AI algorithms among different stakeholders (Bouder, 2020). In the AEC field, this would involve, for instance, developers, engineers, and all other relevant parties working on a project.

A crisis originally denoted "the turning point for better or worse in an acute disease or fever", and nowadays often addresses "a difficult or dangerous situation that needs serious attention" (Merriam-Webster, 2023). Crises in the AEC industry, considering its scale and specificities, are often systemic and severe. The cost of infrastructural projects is usually very high, which also leads to raising costs stemming from any kind of delay within the projects (Hällgren & Wilson, 2008). In addition, Slovic (1987b) when discussing complex industrial systems explains that impact of "unfortunate events" in such systems could ripple outward and cause substantial indirect costs exceeding the initial event. This analysis is reinforced by later research from Renn and Klinke (2004) about the unfolding of systemic risks. In addition, also out-of-the-field large-scale crises such as COVID-19 have an enormous impact on the whole AEC sector (King et al., 2021). We also know that if modelling to express risk is not done appropriately in crisis situations, it could result in extreme scenarios being given more weight than it should (Aven & Bouder, 2020).

However the whole idea of introducing digital technologies in construction comes with abundant promises to tackle known challenges of labour shortage, competitiveness, resource, energy efficiency and productivity (European Commission, 2021). Therefore, the aim of this paper is to investigate how the use of AI and AI algorithms may affect uncertainties in the AEC field, and can it be considered as a crisis prevention tool.

3. Method

To answer this inherently qualitative question, we opted for a research design involving semi-structured, in-depth interviews with the aim of investigating the prospectives of the AI use in AEC, especially the use of AI algorithms in the field. This research adopts a risk science perspective, which offers a solid framework to deepen ones understanding of how technologies may affect uncertainties and how greater resilience may be achieved (Logan et al., 2022). In this particular case the focus is on how employees face uncertainties on an everyday level, and how in this context AI may be used as a crisis prevention tool. We aimed for respondents currently employed in the AEC field, who either use some of the AI tools during their daily work or whose work would be influenced by the AI in the future. To narrow the focus down, we aimed for respondents working in AEC field in Europe. We wanted to better understand their understandings and opinions on the current use of AI algorithms in the field. We also want to grasp how the enhanced use of AI algorithms may influence the uncertainties that they face on the daily level. In particular, could key actors in this sector consider AI technology as a crisis prevention tool, and if so, what could be their thoughts on the prospects of the every-day use of AI within AEC.

After we identified the need for expert interviews the next step was to determine who should be the part of our target group. We decided to use as the main discrimination criterion whether a potential respondent works currently in the AEC field. This criterion ensured that target group members are in contact with the main trends in the industry, and that they are using, will be using or at least will be exposed to AI technology in their daily work. We did not discriminate based on their working positions in accordance with the feedback that we received from the pilot interviews: work positions may significantly vary across and within countries, sub-sectors and even among different companies.

The interview protocol was designed after a comprehensive literature review and following two pilot interviews with three respondents from the field. The final list of themes for the interviews consisted of the current state of AI integration in AEC, uncertainties, crisis, regulation, and prospect of AI use on every-day basis within AEC. Guest et al. (2006) suggest 12 interviews when the goal is to understand common perceptions and experiences of a relatively homogenous group. It could be argued whether our group was entirely homogenous since we did not have as inclusion/exclusion criteria a specific work position for the respondents. We therefore aimed for more than 12 interviews and finally reached 21 respondents to ensure robust sampling and data saturation concerning the scale of study.

We conducted the interviews in October 2023. The interviews were organized starting with the introduction describing the aim of the study. Eight open-ended questions were formulated to provide insights into respondents' perspectives of AI, and AI algorithms in the AEC field (see annex).

4. Results

We conducted 21 interviews with employees from the AEC sector across Europe. Considering the novelty of the topic and the feedback gained after the pilot interviews, reflecting substantial variations even across different companies and cities, we decided to keep the inclusion criteria for respondents on a rather simple level. This way, we were given the opportunity to delve deeper into the understanding of the current and possible future use of AI and AI algorithms in the AEC sector, while reflecting on uncertainties and crisis prevention. The work positions of the respondents encompass a range of roles, including BIM managers, architects, construction site leaders as well as academics engaged in research and lecturing within the field. The interviews focused on 1) their factual understanding and 2) their reflections based on own experiences and subjective viewpoints.

4.1. The Understanding of AI and AI Algorithms

The majority of respondents do not perceive algorithms as a unified concept, but rather understand them to be subject to diverse interpretations across various fields, within the AEC sector itself, across professions, working positions, and different projects. This raises potential challenges, and they highlighted an array of additional uncertainties. For instance:

"An AI algorithm is a model learning the history and predicting the future" (Respondent 2)

Still, most respondents were familiar with the use of AI and AI algorithms in the AEC sector. Examples included drone projects, detecting concrete cracks on dams, tablet with BIM being used by a construction worker, and predicting structural response. Nonetheless, the majority of the respondents had not yet used AI or AI algorithms or were ignorant about the fact that they had. The reason behind this is that, while respondents can easily perceive differences among different applications including nondigital and digital working environments, they appear to encounter more challenges in distinguishing between non-AI-supported software and AI-supported software. For some, the idea of AI remains ambiguous. For example, they associate AI primarily with autonomous driving vehicles and robot-like features, while mainly failing to take into account applications backed by machine learning. During the interviews, several respondents were uncertain about whether BIM, which they use in their daily practices, should be counted as an AI-supported software or not.

Those who were more familiar with the application of AI and AI algorithms in the AEC sector suggested that the design phase could benefit the most from their everyday use. This is because AI can be of assistance during the initial phases of projects and could continue to provide assistance throughout the entire project life cycle, which is normally a time-consuming process. Other respondents also pointed to the important help that AI can offer in areas such as geodesy, structural analysis, and modelling of bitumen quantities. However, we also see disagreements. A few respondents, for instance, explained that AI and AI algorithms could be effectively used by architects. Conversely, a few others completely opposed this idea, reflecting on the challenge of AI to mimic the unique style and individual expressions of architects.

Reflecting on whether the AI and AI algorithms could prevent system failure or potential crises, most respondents highlighted that this could go in both directions. While AI has the potential to prevent potential system failures, or accidents on construction sites, it can also lead to new types of failures, uncertainties, and even crises. The challenge with AI is that it could make some working positions obsolete, and it could even lead to severe employment crises. Also, as multiple respondents report, most projects include numerous stakeholders with many different interests, resulting in various changes throughout the project, making them highly dynamic and demanding. Currently, a lot of work seems to be done based on empirical experience. This could be concerning since, if AI takes over many of their working tasks, employees' prior working experience would not be enough for them to understand and follow the entire working process. Furthermore, as respondents argue this could lead to new types of crises.

Another challenge arises since AI-supported solutions often have an appealing interface and are very intuitive but can also provide inaccurate results due to one or more mistakes in parameters. For instance, a model that was familiar to one of the respondents and was supposed to conduct calculations and provide guidance to heavy machinery operators regarding excavation locations, turned out to be completely inaccurate after a longer period had passed. Due to its appealing interface, this error was only discovered later in the project compared to what would have been the case with older methods. The AEC sector is prone to uncertainties, as respondents state, and AI could amplify them further or generate new uncertainties.

4.2. Are AI Algorithms Good Enough?

Typically, projects within the AEC industry are lengthy, and their structure varies not only from country to country, but also between projects. The high sensitivity of input parameters presents a challenge that respondents frequently observe in today's software solutions used by the AEC sector. Elaborating further, a lot of software packages attempt to convey too many processes, resulting in poor outputs which puts an extreme weight on input parameters. This leads to severe oversights. In that context, one of the respondents described a situation that occurs frequently:

"I inserted all the correct parameters in the software, but the software gave me these bad results." (Respondent 7)

The respondent mentioned that this situation constantly occurred during the implementation of a new, arguably simpler, software used by his company. This, he explained, shows the importance of adequate education for using AI and AI algorithms in the field. Most other respondents reported similar difficulties. As they state, education is one of the major preconditions for successful implementation of AI in the AEC sector. If done correctly, the effectiveness of the algorithms themselves could be assessed better. Most projects involve many individuals, starting with architects, engineers in various positions, but also workers with limited formal education. Thus, it is challenging to enable a good balance and understanding of, for example, advanced, dynamic AI algorithms. This results in a situation where sometimes algorithms work well, yet the human factor is not good enough, which may create an impression that the algorithms are not good enough.

Other respondents also mentioned the challenge of conveying too many processes. Another major issue was the challenge of "one size-fits-all" solutions. For instance, one beam will be exposed to different influence (e.g. of wind, water, etc.), depending on many factors, which is, one respondent argued would challenging to take on board using AI. Another respondent also mentioned a specific issue linked to the digitalization of AI:

"When I see a house, I can recognize by the style used, that the house has been built in the 1930s. However, I see that the façade had been changed during the 2000s and the style does not fit the initial one. I can see that, by having a quick look at the house. Would AI be able to recognize it the same way? Those atypical situations and recognizing the fine details are problematic." (Respondent 15)

Most respondents depicted uncertainties as definitely being one of the key characteristics of AEC projects. They named so-called "model uncertainty", "person uncertainty (e.g. user, developer)", "parameter uncertainty" as a few examples. Uncertainties are especially present in cases of complex, long-term projects. Respondents see AI and AI algorithms as something that may contribute to the efficiency of their work, but on the other hand they argued that it could bring a new set of uncertainties. Therefore, they find it challenging to describe current AI algorithms as good enough to be used on an every-day basis.

In practice, an algorithm's quality is frequently biased towards its appearance. It seems, as the respondents report, that sometimes developers favour creating an appealing interface, rather than putting more weight on data. Visualisation may be highly relevant, but it is important not to forget that the robustness of data comes first. Moreover, this bias towards visual attractiveness may also create challenges on the user side, as errors may be concealed for a longer time compared to the less visually pleasant traditional formats.

Trial periods would play a critical role to see whether AI algorithms are good for purpose. The process should involve experienced engineers who would test their merits alongside classical methods. Additionally, smaller scale pilot projects would make a good start for pre-testing new AI algorithms, before introducing their use onto large scale projects of great significance. Several respondents were of the view that such testing of AI in real-life situations may prevent severe failures or the overlooking of tail uncertainties within more complex projects. Here AI algorithms could be indeed seen as crisis prevention tools. However, multiple respondents emphasized that trial periods will not be able to rule out uncertainties all together. Projects in the AEC field are complex and demanding. There are almost no two identical projects, thus uncertainty will always be present to some extent.

Additional challenge that may occur while using AI and AI algorithms in the field is the need to take into account specific circumstances. For instance, seismic parameters are needed in regions that are more prone to earthquakes. In this case the way forward is to devise dynamic AI algorithms that are flexible enough to follow changing requirements and parameters. For instance, in some countries, regulations define that objects must be constructed taking in consideration a 50 year probability of earthquake occurrence , whereas, hypothetically, no earthquake may occur in the next 300 years. A few of our respondents asked whether an AI algorithm would be able to capture such parameters in a correct and unambiguous manner.

4.3. Regulatory Challenges

Most respondents see the necessity of regulating the AI-supported algorithms used in the AEC sector. Justification stems from lowering the already high level of risks and uncertainties in everyday working environments. Reflecting on the need for regulation, respondents raised the issue of how to best conduct regulatory compliance. Views diverged regarding how this goal should be met. Some highlighted the importance of introducing flexible regulation, while others emphasized the need for stricter governmental intervention.

Yet only few respondents were in favour of standardization. By that they meant Eurocode or ISO-type standards. Still, many recognized the practical limitations of regulation and standardization from the perspective of direct experience. People working on different AEC projects tend to rely to a large extent on the experience that they have acquired from past projects. Existing non-AI-related guidelines are often ignored in favour of experience. This could also pose a practical challenge for future AI regulation.

Instead of relying heavily on strict regulatory compliance, well-trained employees may be more effective at controlling AI implementation. One way of doing this would be to designate a responsible person holding a certain AI license. Different licences are widely used within the field today, so therefore, incorporating another set of licences could be recognized as a simple solution, understandable to the wide range of AEC employees.

A few critical concerns were raised that could pose additional challenges for the reinforcement of regulation. Those are the challenge with the liability issue of AI, ethical and moral concerns, and similar problems. A few highlighted EU Commission as the regulatory authority that could take responsibility on the European level.

4.4. Heading for the Future

All respondents agreed that AI is needed. The reasoning is that AI algorithms could help to simplify many procedures in the field that are currently time-consuming. They also identified trends in other fields and agreed that it is only a matter of time before they spill over to the AEC sector. Algorithms can be very positive, for instance, when using drones for inspection or construction site automation, that can remove the possibility of height fear among workers. The same is valid in the case of not easily approachable terrains.

One respondent formulated a key concern shared by the majority of respondents as follows:

"We have to be aware of the limitations, otherwise the use of AI algorithms can easily lead to new uncertainties, and crises. We have to keep in mind that the data is never perfect, so the results cannot be perfect either. Too much reliance on any software can be harmful, and counterproductive." (Respondent 2)

To name an example, one respondent suggested that it would be very salient to formulate an AI algorithm that helps create working schedules. Yet, while it seems an attractive idea may practical obstacles exist: work phases are very specific, and variability is high depending on the project, the construction site, the workers needed, the operation machines needed, and so on. The question is whether an algorithm could capture such levels of variability and complexity . While all respondents agreeing on this sector's need for AI and AI algorithms, differences were noticeable when it comes to the specifics. More experienced respondents were rather in favour of older ways of running projects. Their view was that AI would be confined to limited tasks such as eliminating redundant tasks. More junior respondents, on the other hand were in favour of larger digitalization and inclusion of AI. However, both groups emphasized that some specific strategic attention needs to precede the introduction of AI and AI algorithms into everyday practice.

Respondents disagreed about *when* AI and AI algorithms will start to be widely used in the AEC sector. A few respondents saw AI to as a longer-term prospect. The main reason, they argue, is resistance to changes. As one respondent explained:

"In the company where I work, we bought a software package that should be of great help for multiple projects we are working on. The investment was very significant, for both the software package and the support in the implementation process. However, eventually it was not used at all, because no one had time to get familiar with the software, and they simply kept doing things the way they have done before, to be able to respect the deadlines." (Respondent 13)

Respondents who saw AI as a shot term prospect also recognized that inertia and habits will delay change. This means that although there are guidelines on how certain projects should develop, people tend to rely on habits acquired in previous projects. The scientific approach in the field is often missing. What is very interesting that even in a same company among different departments there seems to be extreme differences, and different parts of the projects are done in completely different ways.

Education was singled out as the main issue, being even much more relevant than finances and delays needed for the implementation of different AI algorithms. This is especially the case in some basic projects that do not demand a highly skilled workforce. In addition, the challenge with the engineering jobs is that problems then to be solved in ad hoc, atypical ways. The "curve" of physical models is constantly evolving. One aspect from machine learning is how to construct the learning model, and a second aspect is the data side, to follow the real curve as close as possible. As a respondent put it:

"A premise of good control and good data is crucial. For simple structures it is easy to predict, but for the unknown or unknowns we cannot predict" (Respondent 4)

Different fields are included in the AEC projects, which amplify the challenges on how to best implement AI without bringing along a new set of uncertainties by using more dynamic AI algorithms. Therefore, many respondents were in favour of holding a very tight cooperation, good risk and uncertainty communication among engineers who use the AI algorithms and developers who develop them. This appears to be an ongoing challenge within the field when using some simpler software applications. This is amplified due to the specifics of different construction projects. Most respondents raised the need for enhanced risk and uncertainty communication among engineers and developers. Others also suggested to improve risk communication and uncertainty communication among risk analysts and non-engineering positions in the AEC sector.

Simplicity was also mentioned as a must. Introducing AI and algorithms should be done on an easy pace, and as a step-by-step process. Otherwise, the already existing uncertainties may only increase. During projects, there should be a good framework for providing feedback and learning from mistakes early on. The approach should be evidence-based.

A small minority of respondents showed a more sceptical attitude, asking fundamental questions about whether the implementation of AI and AI algorithms in everyday AEC practice is at all necessary. The reasoning behind this is that AI could introduce new uncertainties, leading to new crises. For instance, people may lose their jobs as the learning pace of AI and robots is much faster. This could lead to a loss of institutional memory and skills. Those AI-sceptics also highlighted that the public should be more informed on how these processes work.

5. Discussion

AI and AI algorithms in the AEC sector are generating great expectations as well as significant challenges. The complexities of the AEC sector have slowed developments in this area. Consequently. It remains one of the least digitalized sectors in the world. Respondents throughout all the questions emphasized the significant uncertainties that they already deal with on a regular basis at work. Their responses to the interview questions depict insecurities on how these uncertainties will be dealt with once AI is widely introduced in the field. This suggest that to date AI is unlikely to be of use as a crisis prevention remedy, and that future prospects in this respect are also unclear.

When addressing the understanding of algorithms, most respondents emphasized not seeing them as a unified concept. This aligns with earlier results of a similar study that focused on the application of AI algorithms into precision medicine (Mrksic Kovacevic & Bouder, 2022). However, interestingly enough, most respondents, showed ignorance in employing AI and AI algorithms in their daily work, explaining that the concept of AI appears to be ambiguous. Scholars have reported

similar challenges in different contexts. As White and Lidskog (2022) point out, AI is often used in a very broad manner, making its essence and limits difficult to define. Another relevant example may be found in the European Commission (2021) report on Digitalisation in the construction sector. There, many respondents were not able to provide an answer on the adoption rate of AI in their countries, which they assign to the AI's low visibility in the construction sector. When discussing the use of AI and AI algorithms, the respondents identified design as a phase which could benefit the most with their wider use. According to Baduge et al. (2022) researchers have been successfully using these tools within the architectural design phase. Some respondents also mentioned structural analysis as an example of success. Uncertainty was confirmed as one of the greatest challenges that the AEC sector faces on a daily basis. The respondents recognized the numerous uncertainties that they are facing. They rose a concern that the introduction of AI, especially if inadequately implemented could lead to a new set of uncertainties. An et al. (2021) find that lack of understanding about the inherent uncertainty leading different AI applications to face challenges and limitations in work. Darko et al. (2020) also describe uncertainty as one of the most frequently addressed issues in using AI (Darko et al., 2020). This study's respondents also described the challenging impact of specific rules and atypical situations. In view of previous examples this may lead AI implementation to create new sets of uncertainties, failures, and even lead to crisis. Tengberg and Hagentoft (2019), explain, for instance, using a Swedish construction industry example, that too often the introduction of new technical solutions results in failure, possibly leading to large-scale damages.

Respondents reflected on how to determine whether AI algorithms are good enough to be used in practice. When answering these questions, they typically showed optimism when it came to algorithms' role in aiding to lower the high uncertainties they face within their sector. Here they explained that if AI and AI algorithms are trained on smaller-scale projects, they could be of great aid even as crisis prevention tools, hindering severe failures. However, they also pointed to specific challenges. One is definitely the complexity of providing good training for AI algorithms, as there are almost no two identical projects in the field since each project carries its own set of specificities. Therefore, although they see them as potential remedies for some situations, respondents were concerned about the fact that algorithms could carry a whole new set of uncertainties on board. In such situation, Jiang et al. (2017) suggest the use of sophisticated algorithms to "learn" from big data and then employ the obtained knowledge to offer practical assist. Respondents also highlight the challenge of an appealing interface, which sometimes even in much simpler applications could be misleading. Also, the parameter importance and the challenge of the human factor, may lead to the understanding that the algorithm is not good enough, whereas the error could have been human.

There was wide support for some form of regulation when it comes to the use of AI and AI algorithms in the AEC sector. Respondents even highlighted options such as standardization and possible licenses, but some also mentioned the need for the European Commission to interfere. This wish may be met as the European Commission itself (2021) suggested an EU-level regulatory framework. Yet the main take home message was that regulation will not be a panacea. Existing guidelines, for instance, seem to play a lesser role than direct experience from past projects. Therefore, the importance of having a stronger regulatory requirement appeared as both needed and questioned. Respondents also expressed concerned about transferring too much burden to AI, which could generate many new uncertainties and cause potential crises instead of solving them.

When discussing the future, this study's results show that the introduction of AI and AI algorithms in the AEC field is a matter of time, but it seems that it is not yet imminent. This finding aligns well with observations made in the Digitalisation in the construction sector report (European Commission, 2021). The report concluded that while the EU construction sector is advancing in the uptake of digital technologies, AI still remains in the development stage and cannot yet be considered as market ready. Our respondents highlighted time and costs as highly relevant but did not see them as crucial factors for hindering AI implementation in the field. In their opinion, lack of

education within the field is one of the key elements, which is also consistent with the European Commission (2021) report. There, the cost of equipment and software, the lack of a skilled workforce, and a lack of awareness and understanding of digital technologies are the three main factors hindering the faster and broader digitalisation of the European construction sector. Early on, Slovic (1987a) highlighted the need of education in cases of opposition towards risky technologies. Recent AI literature has confirmed that similar mechanisms are at play in this field. The willingness to use AI depends on the knowledge a person has about the AI. The more knowledgeable are more prone in employing AI (Schwesig et al., 2023). Yet, AI education rest on a science-informed and evidence-based approach. While this approach was described as highly desirable, the remedies to meet this goal are often missing in practice. Additionally, our respondents highlighted the need to enhance the risk and uncertainty communication among developers and engineers working in the field, especially when using AI solutions. Interestingly, in another study that we conducted in the field of precision medicine (Mrksic Kovacevic & Bouder, 2022), risk and uncertainty communication were also highlighted as relevant, but there the role of regulators in it was also emphasized. In the present study, however, the role of regulators was seen as less crucial, and more weight was given to communication among developers and users. Interestingly, many respondents emphasized the need to include risk analysts or risk-educated professionals as an important role in risk and uncertainty communication. We also see multiple calls in the vast risk literature for more and better risk and uncertainty communication despite the complexity of the topic communicated (Löfstedt & Bouder, 2021). Finally, our respondents see the need for a step-by-step implementation process as extremely important, as otherwise we could face much larger uncertainties and even end up in crisis situations.

6. Conclusions

Our study shows the need for wider implementation of AI and AI algorithms in the AEC field. However, this comes with certain challenges. It seems that the use of AI would lead to lowering some known uncertainties, but if not implemented adequately it could bring on board some new ones. One of important challenges as our results implicate is ignorance in using AI and AI algorithms. Finally, AI and AI algorithms could be seen as a crisis prevention tools in certain situations, but again with insisting on AI implementation at any cost, this could backlash and induce new types of crises. A proper strategy for the AEC sector is therefore needed before introducing AI. This strategy should be risk-informed so to mitigate risks and prevent future crises from erupting.

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Resume

Sanja Mrksic Kovacevic has background in Economics, Engineering Management and Risk Management. She is currently conducting her PhD, at the University of Stavanger in Norway, where she is working on developing a risk-science approach to managing and communicating uncertainty in the Big Data age. She is a PhD board member of the Society for Risk Analysis Europe - Nordic Chapter.

Frederic Bouder is Professor in Risk Management at University of Stavanger, Norway. He is a recognised expert in risk policy analysis. He has integrated cognitive insights from decision science into making risk policy more science-informed. He has directed research on the energy transition, pharmaceutical risks, genetic risk communication, AI, food safety and construction among other topics.

Annex

The interview protocol

1. Are you familiar with the integration of artificial intelligence (AI) in the AEC field?
    a) If yes: Could you provide some specific examples?
    b) Do you currently incorporate AI solutions into your daily practices?
        a. If no: do you have plans to do so in the near future?
    c) Do you consider them to be contributing to failure & crisis prevention?
2. How would you define an AI algorithm in this context? Do you think that there are different interpretations of algorithms in the AEC context?
3. How can we assess whether the implementation of AI, and AI algorithms improves the outcomes of AEC projects? Do you believe they are helping in failure and crises prevention?
4. How should we evaluate whether an algorithm is good enough to be used in practice?
5. The AEC field deals with uncertainties on many levels. In your opinion what will be the effect of algorithm use on uncertainties? And what led you to this opinion?
6. Can you identify specific areas within the AEC field where AI applications could be particularly advanced?
7. Are you aware of any examples of algorithms that have been regulated by a formal regulatory body? If yes, can you provide an example? If no, do you think that they should be regulated and by whom?
8. What is the most important thing that needs to be done to move the use of AI algorithms into everyday AEC? Are we heading this way?