Understanding Professional Perspectives about AI Adoption in the Construction Industry: A Survey in Germany

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Abstract –

This study investigates the transformative impact of Artificial Intelligence (AI) in Germany's construction industry. Through a comprehensive survey and interviews with 94 industry professionals, the research explores current AI adoption rates, challenges, and future potential. As the construction sector stands at the brink of digital revolution, the paper uncovers nuanced perspectives, emphasizing AI's tangible force in reshaping this traditionally conservative field. Professionals acknowledge AI's promise in enhancing efficiency, accuracy, and safety, despite facing challenges like a steep learning curve. The study delves into practical AI applications, providing insights into automated keyword search, image recognition, and text editing. The findings reveal a growing interest in AI, signaling the industry's shift towards data-driven operational models and the potential for disruption in traditional practices. The paper concludes with recommendations for education, research, and collaborative engagement in guiding responsible AI implementation.

Keywords –

Artificial Intelligence; Adoption; Change Management, Efficiency

1 Introduction

The construction industry plays a significant role in the global economy. In Germany with construction investments amounting to 475 billion euros, it contributed around 6% to the country's Gross Domestic Product in 2022. Due to its economic significance, the construction sector can undoubtedly be identified as a key industry. However, it is concerning that productivity growth in this sector remains low and that the degree of digitalization is quite low compared to other sectors. [1]

In this context, the use of Artificial Intelligence (AI) offers the possibility of significantly increasing digitalization and productivity in construction companies [2]. AI is emerging as a significant force driving change in this historically conservative sector, moving beyond mere industry buzz [3,4].

This research conducts an extensive survey analysis to explore the perception of German construction professionals, examining the current adoption rates, challenges, and potential of AI in the industry. By tapping into the knowledge of industry professionals, the study provides a refined view of how they navigate this new technological landscape and gives insights about the developing role of AI in the construction sector.

AI's entry into the construction field marks a distinguished shift from traditional methods, offering potential enhancements in efficiency, accuracy, and safety [2,5,6].

Therefore, it is not surprising that interest in the implementation of AI applications continues to grow. This can be seen in the increase of research activities and in the trend of publications in recent years [3]. Expectations for AI applications in the industry are also growing. For example, AI is expected to improve processes with quantitative factors. Here, key factors can be considered the compliance with project schedules, risk analysis and cost estimation, control, and adherence to associated budgetary goals [7].

To meet these expectations, applications from different areas of AI must be integrated. According to [8], AI can be divided into the following sub-areas: Machine Learning, Computer Vision, Automated Planning and Scheduling, Robotics, Knowledge-based Systems, Natural Language Processing, and Optimization.

The Table 1 below illustrates how the construction sector can leverage these AI sub-areas, underscoring the wide-ranging potential of AI to revolutionize traditional practices.

Building on this framework, AI-based systems play a pivotal role across various construction domains. In project planning, AI monitor progress, identify risks, and optimize schedules, enhancing both efficiency and reliability. In design and calculation, AI supports complex processes like generative and parametric design, enabling architects and engineers to push the boundaries

of innovation. Additionally, AI facilitates accurate cost estimations during the bidding process, underlining its value in financial planning.

Table 1 Application Areas of AI in construction (based on [8])

Application Areas / AI subareas	Machine Learning	Computer Vision	Automated Planning & Scheduling	Robotics	Knowledge-Based Systems	Natural Language Processing	Optimization
Health & safety	●	●			●	●	
Scheduling	●		●		●		●
Calculation	●				●		●
Contract & conflict management	●	●			●	●	●
Supply chain & logistics	●				●		●
Construction supervision & performance monitoring	●	●		●	●	●	
Material management	●	●		●		●	●
Construction site assembly	●			●			
Asset & equipment management	●	●		●			●
Project planning	●	●	●	●	●	●	●
Knowledge management	●	●			●	●	
Design	●	●			●		●
Risk management	●			●	●	●	●
Temporary structures	●						●
Bidding and contracting	●				●		
Energy management				●			
Sustainability					●		

The execution phase sees AI's physical implementation through technologies such as 3D printers, robots, and self-driving trucks, marking a significant shift towards automation in construction site assembly. Health & safety management benefits from AI's capability to predict hazards, contributing to a safer work environment. Similarly, in quality control, AI ensure high standards by identifying defects early. For facility management and equipment maintenance, AI extends the life cycle of buildings and machinery through predictive maintenance, illustrating AI's long-term value in sustaining infrastructure.

Nevertheless, the conversion is not free from challenges. Professionals in the industry are facing a hard learning curve, endeavoring to integrate AI into customary workflows, and tackling skepticism about its practical usefulness [5,7,8]. To handle this matter, this research entails analyses of prevailing AI applications, encompassing software, such as Ensun, for automated keyword search, Oculai for image recognition, and Neuroflash for text generation and editing. Furthermore, the research delve into intangible, pivotal aspects of AI adoption [4], touching upon the attitudes, expectations, and apprehensions of the experts that lead this progressive exploration [9,10].

As the construction industry in Germany approaches a digital revolution [9,11], this paper aims to offer a thorough examination of the current state of artificial intelligence (AI) implementation, pinpoint challenges, and estimate the path of AI's revolutionary impact on construction. Through this lens, the research objective is to analyze the technological implications of AI objectively, while exploring the human element by understanding the perspectives, experiences, and visions of professionals at the forefront of this transformative wave.

2 Methodology

A comprehensive methodology was utilized in this study to assess professionals' perceptions of AI in the German construction industry, integrating both survey and interview components.

2.1 Survey

The survey was specifically conducted with the aim of providing critical insights into the implementation of AI applications in the construction sector. Its primary objective was to identify the perceived positive effects and the added value of these AI implementations and to explore the untapped potential of AI in the industry. An additional goal was to ascertain the specific application domains of AI, their various types of usage, and the value they add to the sector. To achieve these ends, the survey aimed to answer the following research questions:

1. What AI-based software applications are already being used by professionals in the construction industry?
2. In what context are these AI-based software applications used?
3. What positive impacts have individuals and their corporate environment experienced through the use of these applications?
4. What additional AI use cases are planned within the company, and what positive impacts are expected from AI usage?

2.2 Target Group

The target group of the survey included professionals at varying levels within the construction industry, such as contractors, engineers, architects, planners, designers, site managers, project managers, IT specialists, and commercial employees [12]. Specifically targeting individuals involved in various construction phases such as design, planning, implementation, operation, and

maintenance, provide a wide range of valuable perspectives.

To contact this target group, a versatile approach was used, relying primarily on a comprehensive list of Germany's top construction companies [13]. Regional contacts, department heads, and CEOs were identified through thorough research of relevant company websites and were sent personalized email invitations. Employees of both subsidiary and subcontractor companies, as well as individuals working for regional construction companies, also received personal invitations. Additionally, the survey was posted on LinkedIn to expand participation to smaller companies and professionals in the construction industry.

2.3 Data Collection

Utilizing Google Forms as the data collection tool, the survey was structured to include a blend of both quantitative and qualitative questions. It commenced with fundamental demographic inquiries, such as age and profession, and then progressed to delineate three distinct AI experience profiles, thereby categorizing participants into the following groups:

1. **AI Experienced Users:** Professionals with direct experience using AI in construction, who have a at least basic understanding of AI and utilize AI-enabled software or tools.
2. **AI Aware Non-Users:** Professionals without experience using AI in construction but are open to implement AI solutions and have knowledge of AI subareas.
3. **AI Skeptics:** Professionals lacking experience using AI in construction and either unable to envisage AI integration in their work or generally resistant to AI adoption.

This segmentation was particularly relevant considering the preliminary assumption of the survey. Prior to its distribution, it was hypothesized that a significant number of companies in the construction industry had not extensively engaged with AI applications, much less implemented them. This assumption shaped the questionnaire's structure as shown in Figure 1 , aiming to elucidate the current landscape of AI adoption in the construction sector extracting information also from non-users and skeptics.

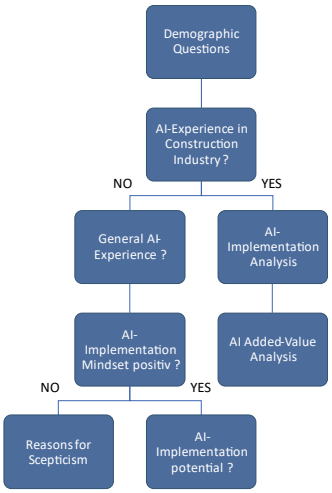

Figure 1. Survey Structure

The questions in each step of the survey aimed to investigate several aspects, including current AI applications in the construction industry, the software domains in which these AI applications are being implemented [6,14], positive impacts from AI application usage, and further anticipated positive impacts from AI implementation. Specifically, for those considering implementing AI, the target was to inquire about the perceived potential of AI. For those with AI expertise, the tangible benefits of AI applications were evaluated and an invitation for a follow-up interview was extended.

Given the space limitations of this paper, a comprehensive list of all survey questions is not included. Instead, we highlight key sections and questions to elucidate the survey's scope and structure more effectively:

1. **Demographic Information:** Queries such as age, professional title, and company size help contextualize the responses, ensuring a broad understanding of the industry's demographic landscape.
2. **AI Experience and Awareness:** This section distinguishes between respondents based on their direct use of AI in construction versus those with general awareness. It includes questions like "Have you had experience with AI in the construction sector?" and "Which AI application areas are you aware of?", aimed at understanding the depth of AI integration and awareness across the industry.
3. **Technology Use:** Inquiries about the types of hardware tools used in professional activities, such as PCs/laptops, smartphones, or AR glasses, are designed to assess the level of technological integration and readiness for AI adoption among participants.

2.4 Interview Methodology

The interviews provided a detailed overview of AI use in the construction industry. The goals were to explore AI implementation and its effects, supplementing the survey findings.

The interviews were semi-structured and conducted via Zoom calls. Transcriptions were made following rules, focusing on simplicity for essential information capture [15].

Despite the small sample size of three experts, the interviews offered valuable insights, although the findings are not representative of the entire industry. The diverse responses highlighted the range of AI applications and their benefits. A combination of categorization and data summary was used to analyze the responses, focusing on:

1. AI use cases.
2. Positive impacts of AI usage
3. Future plans and expectations for AI.

3 Findings

3.1 AI Experienced Users

The survey conducted among professionals in the German construction industry revealed insightful findings regarding the perception and implementation of AI in this sector. To provide a clear overview of the respondent demographics and their AI experience levels, we have summarized the distribution of participants across three key categories shown in Table 2.

Table 2 Summary of Respondent Categories and Their Distribution

AI nowledge Category	Description	Number of respondents	Percentage of total
AI Experienced Users	Professionals with direct experience using AI in construction	22	23.4%
AI Aware Non-Users	Professionals aware of AI but without direct experience in construction	66	70.2%
AI Skeptics	Professionals skeptical about integrating AI into their work	6	6.4%

Of all the survey participants, 23.4% (22 respondents) reported that they have "experienced using AI in the construction sector." Among these, 20 are active in the design phase, 17 in the implementation phase, and 12 in the operational phase. This supports the assumption that the further a construction project progresses, the less AI applications are utilized.

Figure 2 illustrates that those with AI experience have already used AI tools and AI software in every AI application domain. This level of familiarity is considered positive. Furthermore, it is observed that Machine Learning (ML), Computer Vision, and Natural Language Processing (NLP) are the domains where most participants have accumulated experience. Computer Vision is seen as the most promising area; it has been tried by most participants and is nearing the plateau of productivity.

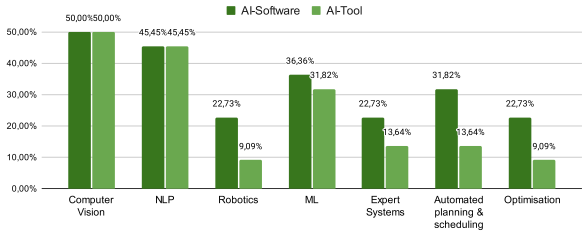

Figure 2. Use of AI applications by AI application categories

AI tools are used slightly more frequently than AI software. 45% of respondents use AI tools and 32% use AI software at least regularly, suggesting that these have become established. The trend towards reduced software usage could be attributed to a longer learning curve or data privacy concerns.

AI usage has been identified with common software products for the construction industry and in support of it.

As shown in Figure 3, when analyzing the software usage, it becomes apparent that documentation software, programming software, and software for the technical management of projects have the highest number of AI implementations. However, the use of AI tools to augment these existing software products is comparatively lower. This disparity suggests that there is no intention to integrate AI tool support into currently used software products. Rather, the trend seems to be either towards replacing existing non-AI software with new AI-enabled products or planning for a seamless integration of AI into existing systems.

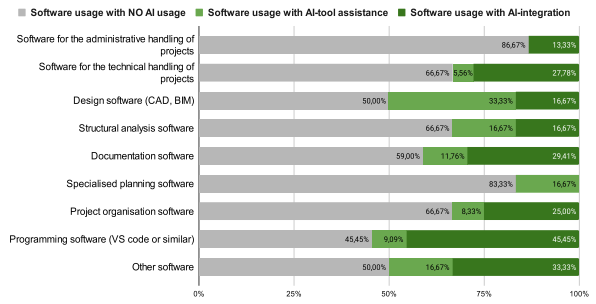

Figure 3. Use of software at work with AI usage

Furthermore, as seen in Figure 4, those with AI experience have generally had positive experiences with AI applications. Additionally, a correlation can be observed between the positive effects of AI and the duration of AI application usage. Participants reported the greatest positive effect when AI software or AI tools were used almost always. However, the results do not indicate any differences in the usage of AI tools versus AI software.

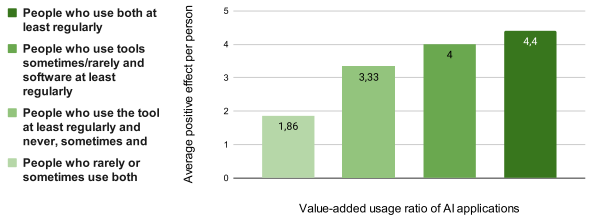

Figure 4. Value-added usage ratio of AI applications

Nearly 78% of the participants report perceiving an increase in efficiency due to the use of AI applications. It is notably positive that at least 50% of the participants also benefit from time savings, automation, and improvements in accuracy and quality. However, only about 32% of those experienced with AI perceive cost savings as a positive effect. It is significant that nearly 30% of the respondents indicate that using AI makes them more innovative or able to generate more ideas. These individuals have an average score of 3.67 regarding the extent of positive effects, which is 0.27 points higher than the average for those experienced with AI. Thus, the few individuals using AI for this purpose tend to benefit more than others. Additionally, 23% report gaining a competitive advantage. Less than 15% benefit from increased customer satisfaction, reduced software errors, and data security improvements. Less than 10% have identified an increase in revenue.

The AI experienced users have a very positive outlook towards further developments. Approximately 78% envision continuing to be supported by Machine Learning (ML). Around 70% of the participants see potential in Computer Vision and automated planning and scheduling, while 64% recognize potential in Natural Language Processing (NLP). Less potential is attributed to expert systems (45%), optimization algorithms (45%), and robotics (41%). In the latter two AI application areas, a lower level of development is observed compared to other AI application domains and subfields.

3.2 AI Aware Non-Users:

This was the largest participant group (66 participants). For these participants, it was important to determine their general knowledge and connection to AI, as they have no experience with AI in the construction industry. As Figure 5 illustrates About 55% of the respondents have heard of Computer Vision, which represents the highest awareness level. The least knowledge is about optimization (Evolutionary Algorithms) with 9%, and approximately 22% have not heard of any AI application area. It is evident that there is a need for education to understand the benefits of AI and later be able to use it.

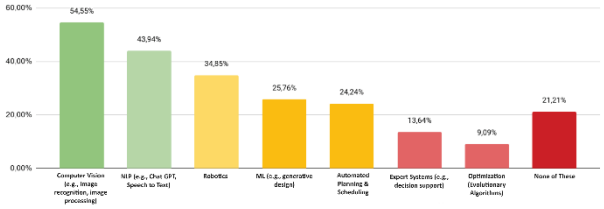

Figure 5. Knowledge of AI Application Areas Outside the Construction Industry

AI applications outside the construction industry have been barely tried or used. A glimmer of hope is the testing and gaining experience with AI applications in the NLP field. Here, nearly 30% of the participants indicate they have already used tools, and 9% have used software (as shown in Figure 6). Chat-GPT can be clearly identified as a catalyst here, likely sparking discussion through its increased media presence and explaining the outlier in an otherwise quite homogeneous testing rate seen here.

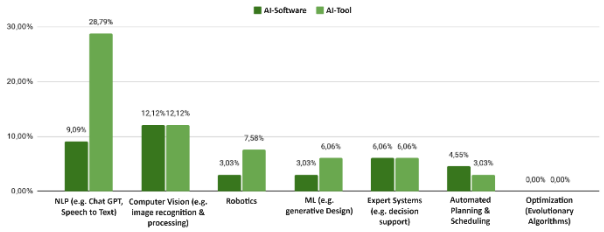

Figure 6. AI applications tried out independently of the construction industry

The expectations regarding the use of AI are also very high in this group. Approximately 87% of the participants, similar to the AI-experienced group, can envision saving time through the use of AI. The top five categories of expectations are the same as in the AI-experienced group, with the percentage differences being no more than 9% (efficiency increase) and similarly high. A larger difference is observed in the promotion of innovation through AI assistance, with a 22% discrepancy. The less positive expectation regarding innovation enhancement could be due to the fact that this category is not extensively demanded during their work activities. Alternatively, it might be that in this group, AI is more often employed for analytical rather than creative improvements.

The results regarding the reasons for the lack of integration of AI applications in their work are very intriguing. The clear main reason for not implementing AI applications at work is the lack of AI expertise, at nearly 70%. Other reasons include a lack of personnel resources (38%) and excessive complexity (28%). It is noteworthy that three-quarters of the respondents citing personnel resource shortages work in companies with at least 250 employees. An infrequently mentioned but relevant reason is the lack of influence over such decisions. The majority of potential influencers in the construction industry are likely not decision-makers but can encourage their superiors to engage with this topic and initiate innovations. Lastly, participants also indicate a lack of overview of AI applications for the construction industry or not having found a sufficiently developed solution yet.

3.3 AI Skeptics

The last of the three groups to be analyzed has not yet had any experience with AI in the construction industry and tends to be averse to the implementation of AI applications. Initially, it was estimated that this group might constitute the largest portion of the survey participants, due to the conservative attitude of the industry in general. Accordingly, a value-added potential analysis regarding their work activities was to be conducted, which aimed to reveal the potential of AI implementation. It is very positive to note that this group only consists of six individuals, suggesting an increased openness towards AI in the industry. However, due to the small number of people in this group, the survey results are not representative.

These six individuals have no experience with AI in the construction industry. Half of them have also not heard of any AI application areas. The other three report familiarity with 1. Expert systems, 2. Expert systems, Computer Vision, and NLP, and 3. Computer Vision, NLP, and Robotics. Despite this awareness, none of the six has tried an AI application.

Five of the six participants state they lack specialized knowledge in AI. Four of them mention the high complexity of the subject and quality concerns. Half report not having the personnel and express security concerns. Additionally, high costs and fear of job loss are cited in relation to the lack of integration of AI applications.

3.4 Interview Insights

3.4.1 AI Use Cases

The usage of AI varied significantly, as all interviewees had different professions and requirements. AI-based software like Ensun for automated keyword search and Neuroflash for text creation and editing were mentioned. Oculai, as an image recognition software for construction sites, was also highlighted. All interviewees mentioned using Chat-GPT, an NLP-based language model, but avoided direct system integration for data protection reasons. The usage ranged from supporting programming tasks to acting as a knowledge database for brainstorming and refining concepts.

3.4.2 Positive Impacts of AI Usage

All AI applications were part of pilot projects, indicating ongoing process changes. A positive attitude towards new technologies and AI was common across all companies. Significant benefits included database creation, assistance from direct AI application use, and elimination of repetitive tasks. AI implementations also spurred employee thought processes on transferring new knowledge to other company processes. Productivity improvements were noted, although not solely attributable to AI. AI applications like Ensun improved internet research efficiency, while Neuroflash facilitated creative writing processes. Oculai improved construction site monitoring, and Chat-GPT was used for brainstorming and decision-making support.

3.4.3 Future Plans and Expectations for AI:

The attitude towards AI in companies is generally positive, with ongoing education on AI's benefits. Expectations vary; improvements in OCR text recognition are anticipated, and NLP applications like Chat-GPT and image recognition are seen as having significant potential. Plans include integrating holistic AI assistance solutions like Amber Search and AI integration in Office 365. AI use in planning and design, such as Autodesk's Spacemaker, is being explored by some of the interviewees. The future of quantum computing and evolutionary algorithms is seen as a key driver for AI development, with expectations for enhanced site safety, monitoring, material transport, and automated machine control. The hope is for AI to fundamentally change the industry's approach and processes. The survey and interview results indicate a mindset of change and the laying of foundational blocks for AI implementation in the construction industry. These findings will help define evaluation criteria and the assessment approach to determine the added value of AI applications for successful implementation.

4 Discussion

The result of the survey seems to reflect a trend in the construction industry related to the positive perception and increased adoption of artificial intelligence to support in different phases of the project lifecycle. A survey done in the U.K. reveals that 22% of professionals currently utilize AI, while a comparable percentage (20%)

indicates their intention to integrate AI into their operations within the next year [15]. These statistics signify a notable departure from previous survey results in 2020, where only 9% of professionals reported using AI. One explanation to these results could be the introduction of ChatGPT. ChatGPT help to position AI in numerous articles, webinars, and conferences praising its advantages while offering guidance on navigating potential challenges. Consequently, the AI technology got closer to different users who could experiment with the technology and started adopting it. Several software vendors are also facilitating the use of AI in theory products via low-code which make it easier for user with no advanced coding skills to leverage basic AI capabilities to optimize processes in the construction industry (e.g., [16]).

Although the results of the survey show a positive trend, there are still different aspect to consider when integrating AI to construction business. The most prevalent in the perspective of professionals related to knowledge about the technology. A significant 70% of participants identified a lack of AI expertise as a major hurdle to embrace AI. This highlight the fact that proper training and education programs related to AI are required. The use of AI in the construction industry also signifies a shift towards more data-driven and more efficient operational models in construction. As AI becomes more prevalent, it could disrupt traditional practices, necessitating a rethinking of current business and operational strategies.

5 Limitations

The study involves 94 participants in the German construction industry context. This needs to be considered when attempting to generalize the findings. The subset of participants invited for in-depth analysis could also introduce company-specific perspectives that warrant careful consideration when interpreting findings related to positive developments, utilization outcomes, and usage trends. Additionally, while this study provides a comparative analysis with AI adoption rates mentioned in the UK survey, it must be emphasized that the methodologies between the surveys are not identical. Consequently, the statistics referenced in our study are intended to be referential and are not meant for direct comparison.

6 Conclusion and Recommendations

This study investigates the transformative influence of AI within the construction sector in Germany. By conducting an extensive survey and interviews involving 94 industry experts, the study examines the present rates of AI adoption, the challenges faced, and the prospective future impact.

The survey reveals a positive trend in the adoption of AI, particularly in early phases of the project lifecycle. The results seem to mirror a positive global industry trend potentially influenced by the introduction of popular AI tools such as ChatGTP.

The identification of lack of expertise as one of the main barriers to AI in the construction sector calls for attention to training/education programs required to facilitate the adoption of the technology in the industry.

Various stakeholders, including academics and professionals with an interest in digitalization within the construction industry, can leverage the insights presented in this study. By doing so, they can gain a comprehensive understanding of AI implementation, enabling them to identify potential risks, formulate effective strategies, and develop a roadmap for the successful integration of AI in the construction sector.

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