A mixed methods approach for investigating the applications of Natural Language Processing (NLP) in Construction industry

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Abstract
Although Natural Language Processing (NLP), a branch of Artificial Intelligence (AI), is not a new concept, it experienced major advances long after its introduction and became one of the most active trends in the last decade due to its various applications. Moreover, the construction industry is a multifaced, and complex sector with countless pressing challenges. It has been slow in terms of digitization compared to other industries, which hinders applying NLP. However, there is an immense potential for applying NLP to facilitate various tasks in construction.
The main purpose of this research is to investigate the need for potential NLP applications in the construction industry to inform pertinent future work. A mixed method approach is adopted in which both quantitative and qualitative data are gathered and analyzed. In the first stage, a group of professionals were handpicked for semi-structured interviews. The results of the study have identified and ranked potential applications, benefits, challenges, and implementation requirements of NLP in each sub-domain. In the second stage, an online survey was designed and distributed to a large group of industry practitioners focusing on a specific approach, identified in the first stage. Both surveys indicate that current approaches are inadequate, and there is a significant inclination and expectation within the construction industry to leverage NLP technology.

Keywords: Natural Language Processing (NLP), Natural Language Generation (NLG), Natural Language Understanding (NLU), Semi-structured Interviews, Construction Engineering, Industry survey, Mixed Methods

1 Introduction

Artificial intelligence (AI), characterized by the development of intelligent models that emulate human cognitive processes, is transforming a myriad of sectors, including construction (Abioye et al., 2021). Despite its potential, the construction industry remains one of the least digitized sectors (Bello et al., 2021). Due to this fact, numerous studies over the past decade have investigated the implementation challenges of digital technologies such as AI in construction (e.g. Abioye et al., 2021).

Recent advancements in graphical processing units (GPUs) and large language models (LLMs) have ushered in significant progress in Natural Language Processing (NLP). NLP, a domain of AI focusing on machine-human language interaction, allows machines to comprehend and interpret human language (Tixier et al., 2016a). The utilization of NLP technologies has become more recognized, especially with their increased accessibility to the public. However, the full potential of NLP has not yet been realized across all industries including construction. For example, a significant portion of construction documents consists of complex and unstructured text, which presents unique opportunities for the application of NLP technologies (Soibelman et al., 2008).

The main purpose of this research is to investigate the practical perspectives and expectations of professionals in the construction industry regarding NLP technology, to find the challenges for its implementation, and to explore further the most desirable suggested applications. This research involves two surveys. In the first one, a semi-structured survey is conducted with 25 professionals. The potential applications of NLP and the barriers to fully utilizing it in the construction industry have been gauged. Based on the results of this survey, a second survey, which is an online survey completed by 73 professionals, focuses on one specific suggested application by the participants in the first survey and identifies practical future work.

This paper reviews existing literature on NLP applications in the construction industry and discusses the results of the surveys conducted. The implications of these findings are considered in the broader context of digital transformation in the construction industry.

2 Literature Review

The practical implementation of NLP technology within the construction industry remained limited due to the inherent complexities and unique characteristics of this sector. Recent advancements in NLP have the potential to significantly impact various sectors, notably the construction industry, which is undergoing a digital transformation under the Industry 4.0 paradigm. Ding et al., (2022) conducted a comprehensive review of NLP technologies within this context, categorizing its applications into document and information management, accident analysis and safety management, automated compliance checking, building information modeling (BIM), risk management, and other diverse applications. Wu et al., (2022) extended this categorization by differentiating the subcategories, such as information extraction, document and information exchange, compliance and regulatory check, risk management, project management, and client and stakeholder communication. Chung et al., (2023) categorized potential NLP applications in construction into automated document analysis, information retrieval, and knowledge discovery. Shamshiri et al., (2024) further introduced multiple sub-categories for NLP, such as cost management, schedule management, quality management, advanced work packaging, facility operations and maintenance, stakeholder management, contract management, safety management, building information management, knowledge/document/information management, and automated compliance checking. They emphasized the necessity for interdisciplinary research to develop tailored NLP solutions that address specific needs within the construction sector. Saka et al., (2023) explored the role of conversational AI, a product of advancements in NLP, and highlighted its potential to improve interactions on construction sites within the architecture, engineering, and construction (AEC) industry. They noted that conversational AI is particularly suited for the information-intensive and physically demanding environment of construction sites, enhancing information retrieval and extraction from BIM systems and other digital platforms. Although reviewing the existing academic papers on NLP applications in the construction industry can be helpful in identifying challenges and potential applications, we believe that conducting a well-designed interview with the professionals in this industry to realize their real needs will be beneficial.

Regarding the current academic research, Tixier et al., (2016a) investigated an NLP system designed for automated content analysis aimed at enhancing construction safety. This system efficiently scans unstructured textual injury reports to extract over 100 variables, showcasing the practical utility of NLP in improving safety outcomes. Furthering this application, Tixier et al., (2016b) integrated this NLP system with machine learning algorithms to predict safety outcomes, thereby aiding decision-making in the construction industry. These two works are true examples of one of many applications that NLP offers to the construction industry.

Another example of NLP application in the construction industry is reported in (Nabavi et al., 2023). They discussed the use of NLP to facilitate non-technical user access to BIM information, employing tools such as support vector machines (SVM) and latent semantic analysis to interpret user queries and retrieve relevant information from BIM models.

Corneli et al., (2023) proposed a system that allows for vocal queries to interact with BIM models, making information retrieval possible through spoken or visual formats. This system aims to make BIM more accessible, especially on construction sites where using traditional interfaces may be challenging. This work considers the conditions present in construction sites. However, these

environments typically have significant noise levels, which limit the effectiveness of voice recognition systems.

Our assessment suggests that NLP experts should direct their focus toward addressing the specific needs and conditions of the construction industry to facilitate deeper integration. Efforts should align with the practical requirements and working environments of this sector to enhance the acceptance and utilization of NLP technology within the industry. The identification of needs and challenges was the motivation to conduct interviews with professionals in the construction industry.

3 The surveys

3.1 Identifying application domains and challenges

For the first survey, the participant selection process was carefully managed to ensure full representation of the various roles and types of stakeholders in the construction industry in Quebec. The participants mainly worked for large construction companies in Canada, which are often leading the adoption of new technologies in this sector. In total, 25 participants took part in the first survey, comprising 20% women and 80% men. Their roles included 32% managers, 28% directors, 20% engineers, and 20% in other positions.

3.1.1 Choosing the survey method

The semi-structured interview method was chosen for its flexibility and ability to provide structure with pre-defined questions while allowing participants to elaborate. This flexibility is crucial in the diverse field of construction, where opinions and experiences vary significantly. Semi-structured interviews enable in-depth exploration, allowing participants to express their ideas freely and investigate unforeseen areas, which is vital in the evolving field of NLP. Additionally, they allow for a thorough initial explanation followed by a discussion where participants can share their thoughts and experiences.

3.1.2 NLP application domains

Based on a bibliographic review, we have organized the capabilities of NLP into five distinct groups. These groups, each offering unique benefits, are listed in Table 1. This classification was used to structure the interviews.

Table 1. Natural Language Processing Subdomains for Interview

NLP Subdomain	Definition	Examples
Chatbots	Automated computer programs equipped with NLP capabilities that engage in text-based or voice-based conversations with users, providing information, assistance, or even performing tasks.	Users can ask the chatbot questions about project updates, safety guidelines, and the chatbot responds in real time, improving customer service and information access.
Information Retrieval	Searching and accessing relevant data or documents from databases and archives. It helps construction professionals quickly locate specific information needed for project management or decision-making.	The Information Retrieval system allows professionals to enter specific keywords to quickly locate and retrieve the most recent blueprint document.
Data Classification	The process of automatically categorizing or labeling textual data into predefined categories or classes based on its content.	In construction project management, text classification software categorizes incoming emails into folders such as “project updates”, or “Safety Reports”, making it easier for teams to manage and prioritize their communication.
Speech Recognition	Converting spoken language into text allows construction professionals to interact with devices and software using their voice.	Speech recognition in construction lets workers use their voice to quickly record and document tasks and observations on the job site.
Machine Translation	Automated process of translating text or speech from one language into another using computer algorithms and AI	In an international project, the machine translation software instantly converts construction documents from English to the local language, enabling effective communication with the local workforce and contractors.

3.1.3 The interview process

The semi-structured interviews were conducted in 35 minutes and aimed to gather essential information on the perception and understanding of NLP technology within the construction industry in Quebec. The interviews included the following segments: (1) Presentation of the participants (5 minutes): The interviewees were asked about their information such as their name, role in the construction industry, relevant professional experience, and the projects in which they have been involved; (2) Knowledge of NLP (5 minutes): The interviewees were asked about their familiarity with NLP; (3) NLP applications (10 minutes): The interviewer outlined the top five applications found in the study, and each participant was encouraged to provide specific examples, practical uses, or potential applications in the context of the construction industry in Quebec. The participants were also invited to prioritize these applications, identifying those they consider most relevant and useful for the industry; (4) Challenges (5 minutes): The participants were encouraged to share their views on possible obstacles; (5) Key success factors (5 minutes): The interviewees were asked to explain the essential factors for the successful adoption of NLP in the construction industry; and (6) Steps for NLP integration (5 minutes): The interviewees were invited to discuss the key steps that they consider necessary to successfully integrate NLP in the construction sector.

3.2 The second survey

The online survey aimed to assess the use of artificial intelligence (AI) and NLP to enhance search functionalities in BIM tools. A total of 73 participants comprising individuals actively working in various capacities, ranging from on-site project management to design and planning, with a technical background in civil/structural engineering: 29 participants, architectural engineering: 28 participants, mechanical/electrical engineering: 8 participants, facility/asset management: 8 participants and 17 participantswith other or no selections for their technical background took part in this survey. Before responding to the 17 questions on the Likert scale, participants were invited to watch a demo video illustrating the project's objectives and were provided with definitions of BIM tools, BIM models, and text-based search functionalities. This preparatory step ensured that all participants had a uniform understanding of the key concepts, thereby improving the reliability and validity of their responses.

4 Analysis of Results

4.1 The results of the first survey

4.1.1 Interviewees' Knowledge about NLP

The participants were asked about their knowledge of NLP. There were 36% who knew a little about NLP, 32% had intermediate knowledge, 8% had good knowledge, 24% knew nothing about it, and there was not any interviewee who had very good knowledge about NLP.

4.1.2 Suggestions and Expectations

To identify areas in the construction industry that could benefit from NLP applications, participants were asked about their perceptions and experiences. They were encouraged to express their ideas openly, and their comments were categorized to identify common themes and potential applications. Participants could propose multiple applications across different subdomains, thus the cumulative percentage exceeds 100%.

For instance, participants suggested various potential applications for chatbots. Specifically, 68% of participants indicated that chatbots could assist project designers and managers, 28% mentioned their utility for on-site construction teams, 24% believed they could aid in reporting project updates, and 8% suggested that these chatbots could support the clients.

The suggestions from interviewees regarding information retrieval were categorized as follows: 64% of interviewees agreed on the benefits of using NLP's information retrieval feature in smart search for precise information. Advanced analysis for construction problems in the domain of information retrieval was suggested by 12% of participants. Additionally, extracting key information from unstructured data was recommended by another 12% of interviewees. Other applications, including contract management, resource monitoring, smart research for suppliers and materials, and risk analysis, were considered beneficial by over 16% of participants in total.

Approximately 45% of participants believed that text classification using NLP can be advantageous for the automated classification of project documents and reports. Additionally, 32% agreed that it could be beneficial for the classification and categorization of routine problems. A further 12% suggested its usefulness for quality control of documents and managing unstructured data. Other applications, such as the automated classification of emails and the evaluation of subcontractor performance, were collectively suggested by 16% of participants. Notably, 8% of participants did not perceive any applications for this field.

Approximately 60% of the interviewees identified real-time transcription as the optimal application of speech recognition technology. About 25% concurred that offline transcription during meetings represents the most advantageous use case. Data entry was favored by 12% of participants, whereas 8% did not identify any application for speech recognition.

For machine translation, 52% of participants indicated that this technology would be useful for translating project reports and documents. Additionally, 16% believed it could be beneficial for translating standards and regulations, and 8% suggested its utility for multi-language training of workers. Notably, approximately 25% of participants did not identify any specific application for this feature.

Figure 1 shows a comparison between the suggestions and expectations.

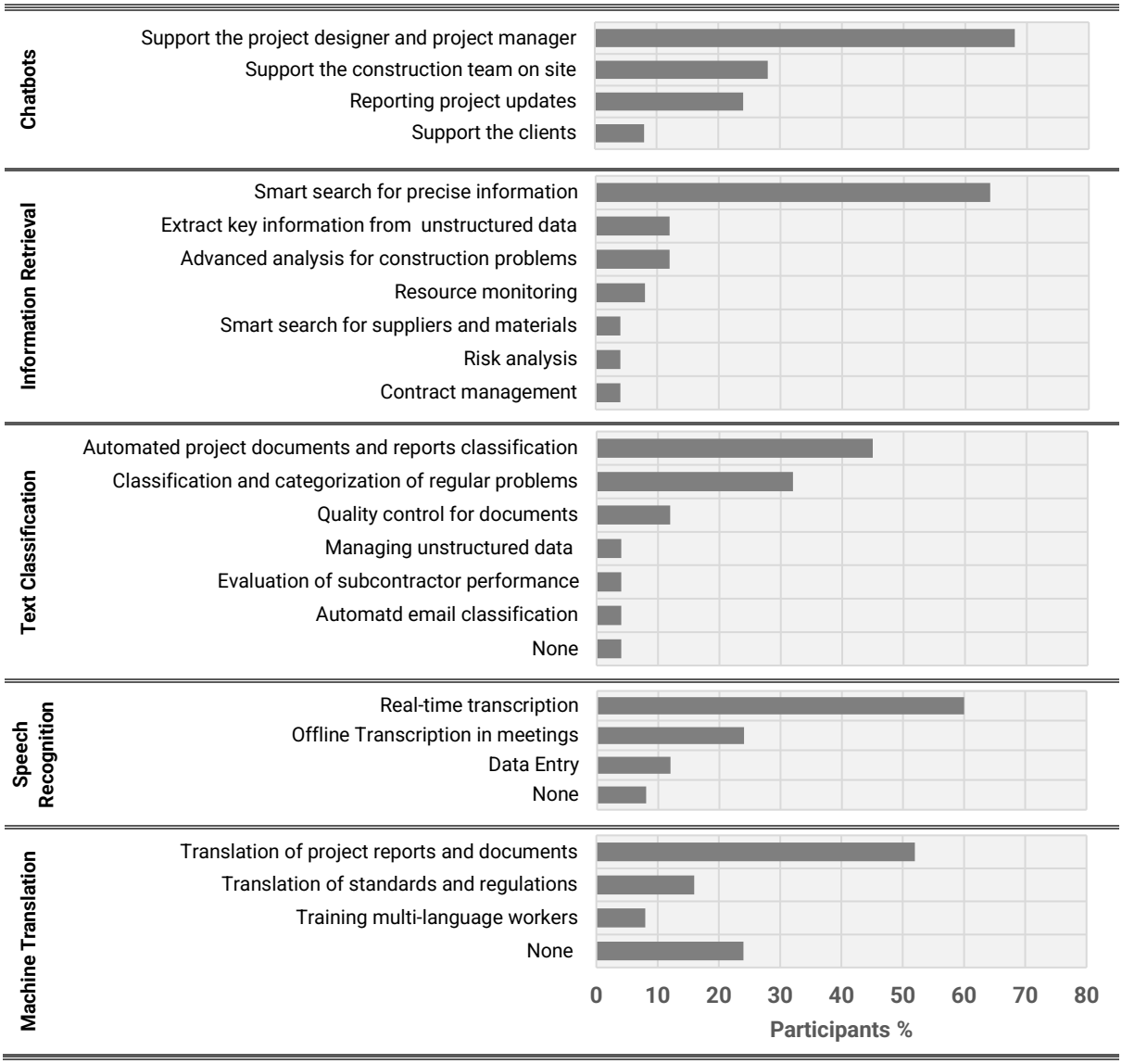

Figure 1. List of expected applications for each subdomain of NLP suggested by interviewees

4.1.3 Priorities

In this survey, participants were asked to prioritize various domains of NLP related to their needs in their roles in the construction industry. The results indicate that the primary choice among participants is the use of information retrieval applications, followed by chatbots. Specifically, most clients prioritized information retrieval, whereas approximately half of the entrepreneurs selected chatbots as their first choice. Notably, despite its potential applications, machine translation was not among the first or second priorities for any participants. An intriguing finding is that as participants' knowledge of NLP increases, entrepreneurs tend to favor chatbots, while clients increasingly prioritize information retrieval. Figure 2 depicts these priorities.

4.1.4 Challenges

During the survey, participants were asked to discuss the challenges associated with implementing NLP applications in the construction sector. Their responses were standardized and categorized into several key areas. In total, the following challenges were identified by the interviewees, considering that each participant was able to suggest multiple items.

Data Reliability: Over 50% of participants expressed concerns about data reliability. The construction sector requires information generated by machines to be precise and accurate. This highlights that a major challenge for applying NLP in construction is ensuring the accuracy of the generated data.

Ease of Use: 28% of interviewees believed that NLP systems should be designed with intuitive user interfaces to facilitate seamless adoption by professionals in the construction sector. Focusing on user experience can help minimize barriers to the daily use of this technology.

Resistance to Change: More than a quarter of participants acknowledged resistance to adopting NLP techniques in the construction industry. Professionals in this sector may be reluctant to abandon traditional methods in favor of innovative solutions offered by NLP.

Data Privacy and Security of Access to Information: Approximately 25% of interviewees were concerned about data confidentiality. Protecting sensitive information against unauthorized access is essential to guarantee the confidentiality of customer data.

Initial Cost: 24% of professionals identified significant financial challenges associated with adopting NLP. This includes investment in hardware, software, and staff training.

Regulatory Compliance: Although only 12% of interviewees expressed concerns about compliance with industry standards and potential legal issues, this remains an important aspect for NLP systems to address.

Other Challenges: Additional challenges identified include responsibility, user satisfaction, real-time data analysis, continuous maintenance, adaptation to different project types, and traceability of actions. Overall, 20% of participants highlighted the diverse concerns that professionals have regarding the adoption of NLP in the construction industry.

4.2 The results of the second survey

In the second survey, building on the initial survey results, which identified information retrieval as a critical need for professionals in the construction industry, questions were meticulously crafted to assess the participants' experience with data in BIM tools, as the main repository of the construction data. Additionally, the survey aimed to provide a clearer understanding of the potential impact of NLP technology in this domain. The results depicted in Figure 4 demonstrate that the satisfaction level with current search tools is significantly low. Participants indicated a substantial need for the application of NLP-based technologies in the use of BIM. The results of the second survey will guide future work and will be aligned with the needs of construction industry professionals.

5 Recommendations and Limitations

5.1 Recommendations

NLP solutions, particularly in the domains of chatbots, information extraction, and text classification, have demonstrated substantial potential during semi-structured interviews with construction professionals. These technologies are promising for managing the extensive textual data generated in construction projects and align well with the ongoing digital transformation in the sector. NLP can

efficiently process unstructured information, automate repetitive tasks, and enhance both communication and operational efficiency. Specifically, chatbots are crucial for optimizing project management through real-time updates, facilitating access to vital information, and providing continuous support to field teams. Information extraction contributes to streamlined document management by automating the search and analysis of key information across various documents. Text classification effectively organizes data, enabling easier access and analysis, thereby enhancing decision-making processes and workflow efficiency.

Figure 2. Priorities of NLP application domains

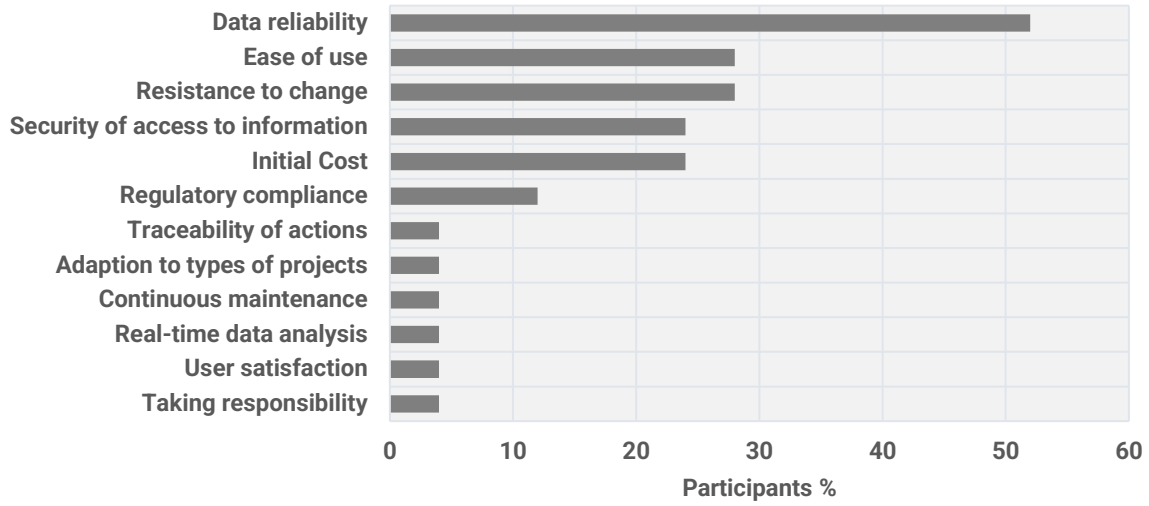

Figure 3. Challenges for NLP systems

Challenges and Considerations

Concerns have been raised regarding the reliability of data produced by NLP tools, including chatbots and information extraction systems. The potential for data errors necessitates a heightened emphasis on ensuring data precision within this industry domain.

The construction industry's diverse needs require versatile and adaptable NLP solutions. Modular solutions that allow customization to specific project requirements are recommended to ensure flexibility and seamless integration with existing processes.

Additionally, concerns about the confidentiality of sensitive information are prevalent in the construction industry, especially when using NLP technologies. Implementing stringent security measures, such as data encryption and secure server usage, is crucial. Besides, it is essential to integrate privacy-preserving techniques to ensure that sensitive data is not exposed or misused. Collaboration with cybersecurity experts is advised to bolster data protection measures and establish robust privacy protocols. By embedding privacy and security measures into the NLP systems, construction companies can safeguard sensitive information, ensuring compliance with regulatory requirements and maintaining the trust of stakeholders. Moreover, regular security audits and updates can further enhance the protection of sensitive data, making the use of NLP in the construction industry both secure and reliable.

Another challenge is the availability of data suitable for training datasets for AI models. Much of the data in this domain is private and not shared publicly. Developing an open-access domain specifically for NLP models in this field would be beneficial for calibrating and tuning these models.

5.2 Limitations

While our research provides valuable insights, many limitations related to the study should be considered to ensure a careful interpretation of the findings.

The study involved a limited number of professionals, from a specific geographical area, potentially limiting the representativeness of the results across the diverse construction industry. Future research could benefit from a larger-scale study incorporating a broader array of companies to enhance the generalizability and robustness of the findings.

Our findings suggest a positive intention among professionals to integrate NLP technologies into construction process management. However, it is crucial to acknowledge that intention does not necessarily translate into successful adoption. Practical challenges such as compatibility with existing systems, budget constraints, and organizational barriers might impede the effective implementation of these technologies. Our study primarily captures this intention and does not assess the actualization of technology integration in practice.

Although our study considers the global aspects of the construction process, a more detailed analysis focused on specific subdomains within the AECO/EM industry could provide deeper insights. An approach examining the unique needs and challenges of segments, such as contractors, engineering firms, and clients could yield more tailored recommendations.

These limitations underscore the need for cautious result interpretation and highlight the necessity for more comprehensive and focused future research. Such efforts would further elucidate the practical challenges and opportunities associated with adopting NLP technologies in the construction industry.

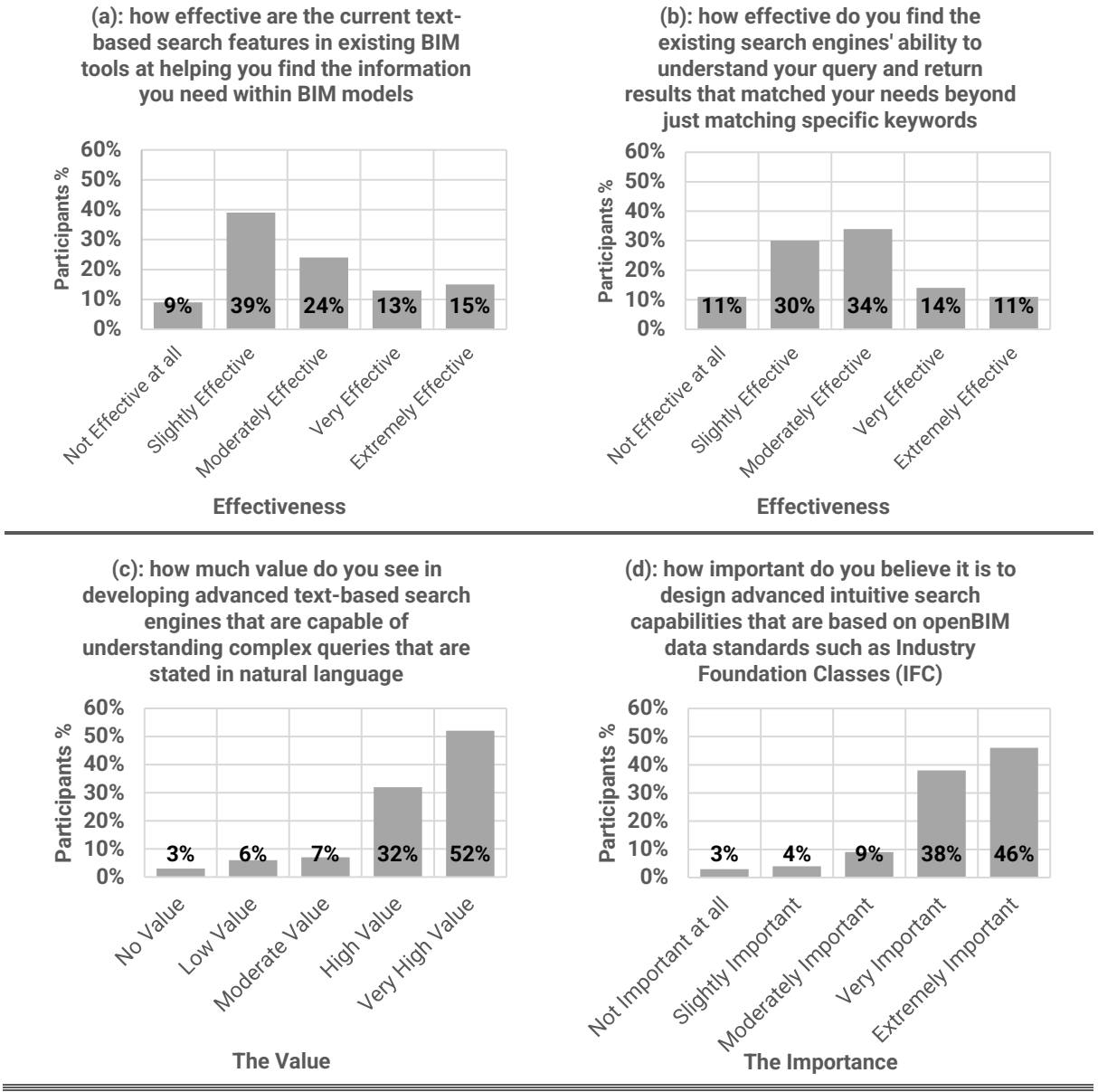

Figure 4. The results of the second survey

6 Conclusions

This study was initiated to evaluate the construction industry's perspectives on the potential adoption of NLP technology. It began with a literature review to establish a foundational understanding of NLP's applications within the sector.

The research methodology included in-person semi-structured interviews followed by an online survey, which provided deep insights into the perceptions and challenges anticipated by industry

stakeholders. These interviews elucidated professionals' expectations, concerns, and emerging trends regarding NLP technology applications such as chatbots, information extraction, text classification, machine translation, and speech recognition.

Findings from the study indicate a substantial interest in leveraging NLP to address operational and informational challenges in construction. However, the integration of this technology faces significant obstacles including data reliability, confidentiality issues, resistance to technological changes, and usability concerns.

In summary, this research provides indications of the readiness for NLP technology adoption within the construction industry. It lays a groundwork for future research, guides more focused future work, and helps identify challenges and find strategies to overcome them.

As NLP technology continues to evolve, it presents valuable opportunities for enhancing efficiency, transparency, and innovation in construction process management, contingent on the industry's proactive engagement with these advanced tools.

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