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Assessing Drivers and Barriers to the Adoption of Smart Technologies in the Construction Industry: A Quantitative Study

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ABSTRACT

The adoption of smart technologies in the construction industry presents both significant opportunities and challenges. This study aims to offer beneficial insights to industry stakeholders by exploring the factors that influence and hinder the integration of smart technology into construction projects. The research discovers that government policies, client demand, technical expertise, top management support, and technology awareness are some of the key factors influencing technology adoption processes. These aspects are identified through an extensive review of the literature. The methodology involves a structured questionnaire distributed among construction industry professionals to gauge their perceptions of drivers and barriers to smart technology adoption. The results of the data analysis establish how significant it is to have the support of the top management, technical expertise, and client demand for technology adoption initiatives. However, barriers such as the complex nature of construction projects, lack of management commitment, and inadequate technological experience emerge as significant barriers hindering widespread adoption. Recommendations are proposed to address these challenges, emphasizing the need for leadership commitment, investment in skill development, client engagement, and collaboration with governmental bodies to create supportive regulatory frameworks. By overcoming these barriers, construction firms may utilise smart technology to boost productivity, efficiency, and industry competitiveness, leading to beneficial improvements in the industry.

1. **Introduction**

Smart technologies as an advanced combination of information and communication technologies (ICT) that facilitates data integration, presentation, processing, storage, and communication [1]. Furthermore, smart technologies are positioned at the centre of technical innovation due to their capacity to redefine the current construction processes that are executed [2]. As a result, smart technologies have several applications that enable them to be integrated with various processes at different stages of a project's life cycle. Primarily, smart technologies fall into five various classifications of technologies (data acquisition, data analytics, data visualisation, communication, and construction automation) based on the objectives for which they are applied [3]. First, radio-frequency identification (RFID), the Internet of Things (IoT), drones, and photogrammetry are examples of smart technologies rendering data collection easier. For monitoring and tracking construction progress, these smart technologies have effectively solved the time delays and compromised precision related to current data-collecting methods [4]. Due to the data-intensive nature of the construction industry, smart technologies like big data and artificial intelligence (AI) are needed because of their ability to process enormous volumes of data [5]. This will enhance the capacity to manage data efficiently, empowering the construction industry's stakeholders to make well-informed decisions in real-time. Furthermore, technologies that facilitate data visualisation are categorised as Virtual Reality (VR), Building Information Modelling (BIM), and Augmented Reality (AR). Additionally, these smart technologies offer a broader understanding of the construction process in a virtual setting [6], particularly throughout the project planning and design stages, it assists the stakeholders gain more understanding of the endeavour. However, to maximise the efficiency of the planning, designing, and monitoring workflow, visualisation technologies are increasingly being integrated with data collecting technologies [7]. Finally, smart technologies that automate construction operations include robotics and three-dimensional concrete printing. These smart technologies have been proven to significantly modify traditional construction methods, especially concerning the number of processes and employees [8]. Consequently, worker safety will be enhanced, construction operations will be more effectively executed, and remarkable results are expected. The research aims to conduct a comprehensive exploration of the drivers and barriers influencing the adoption of smart technologies in the construction industry. This research attempts to offer useful insights for stakeholders in the construction industry by exploring the factors that influence the adoption of these technologies and pinpointing the barriers to their application. To achieve this aim, the research will investigate the primary drivers behind the adoption of smart technologies by construction firms, as well as the barriers that are poised for their widespread integration in construction projects. It will also analyse the impact of various factors on technology adoption, government policies, client demand, technical expertise, and top management support. Finally, it will offer recommendations to eliminate these barriers in maximising the benefits of smart technology adoption in the construction industry. This research aims to contribute to the body of knowledge on the adoption of smart technology in construction by thoroughly exploring these issues. By clarifying the complexity of technology adoption processes and providing practical recommendations, this research aims to enable well-informed decision-making and stimulate constructive transformations in the industry.

2. Literature Review

2.1.Adoption of Smart technologies

Several researchers such as Loosemore [9], Barbosa et al. [10], and Chen et al. [3], have identified the increasing demand for the adoption of smart technology in construction projects to enhance construction efficiency. Accordingly, smart technology has been categorised as electronic tools, mechanisms, assets, and devices that produce, store, or process data [11]. Adopting smart technology is typically done to maintain market competitiveness [12]. The adoption of smart technologies is primarily undertaken to enhance adaptability, effectiveness, and collaboration in managing business processes, including manufacturing, logistics, marketing, and services or materials procurement [13, 14]. According to Chen et al. [3], the key objectives of construction firms implementing smart technologies are to enhance communication among project stakeholders, automate construction processes, and obtain, visualise, and analyse data. Smart technologies that are widely used include Building Information Modelling (BIM), RFID {tracking and tracing), immersive media (such as augmented and virtual reality), and embedded sensors [3, 15, 16].

2.2.Smart Technologies Adoption Process

As seen in Figure 1, the three steps of the technology adoption process include investigation, design, and implementation [17, 18].

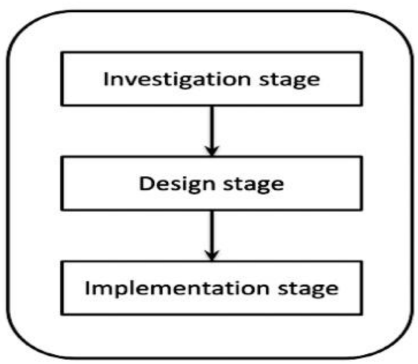

Figure 1. The Construction Smart Technology Adoption Process [17].

According to Sepasgozar et al. [17], the investigation stage usually starts with identifying the drivers and barriers to adopting smart technology in construction. Adopting construction smart technology is hindered by barriers, which are the causes and sources of motivation [19]. In addition, the construction firms must identify the vendors of construction smart technology and improve their understanding of the technologies that comply with the specified drivers throughout this stage. Analysing and assessing the requirements, technologies, and technology suppliers found during the investigation stage are all part of the decision stage [18]. Managers at the operational and strategic levels must be involved at this point [17]. For instance, this step comprises an evaluation of potential vendors of construction smart technology as well as a trial demonstration of the technologies' applicability [18]. During the implementation stage, which frequently comes after testing the technology, the organisation makes the most use of construction smart technologies. Rogers [20] states that the adoption process continues until the technology has been established and is routinely utilised by the adopter.

Chen et al. [3] draw attention to the distinction between using technology for research and development and utilising it following practical implementation. Here, "application" refers to the afterwards, which is the outcome of the adoption process for smart construction technology. The adoption of smart construction technologies may impact organisational, cultural, and technological contexts and result in major changes to the construction process [11, 21]. Construction is one of the industries with the least use of smart technology [23], and construction procedures are behind in adopting digital technologies. Adopting smart technology in construction is a complicated and reactive process for construction firms [23, 24]. Jacobsson and Linderoth [24] draw attention to the limited time of a construction project and the contractual arrangements between the concerned stakeholders, which clash with the in-definite ambiguous and vague adoption process of construction smart technology. According to Lindblad [26], firms in the construction industry use technology in a diversified approach, with project managers and senior managers exhibiting varying levels of optimism, ability, and motivation to commence or participate in the adoption process. Earlier studies have demonstrated that implementing smart technologies in construction projects requires setting up distinct operations to speed up the adoption process [3]; developing channels of communication and collaboration among the stakeholders in the adoption process [24]; adjusting leadership styles and perspectives [27, 28]; developing a digitalization strategy [23] and implementing new regulations and educational initiatives in place [3]. Koch et al. [23] contend that, in light of the implications of smart technology adoption, the process of adopting smart construction technologies ought to be properly overseen through appropriate resources. Chen et al. [3] address the requirements for the adoption process of smart technology in construction that is effective. More study is necessary to properly describe and explain what effective adoption of smart building technologies implies and the necessary resources for such adoption.

2.3. Drivers for Adoption of Smart Technologies in the Construction Industry

The adoption rate of smart technology in the construction industry is significantly influenced by government policies. These policies, which include regulations, guidelines, procedures, and managerial decisions, offer construction stakeholders standards for operating and enable managers to make well-informed decisions on integrating smart technologies. Researchers like Marzouk et al. [29] and Tan et al. [30] emphasise the significant function government policies serve in encouraging the adoption of smart technology in the construction industry. Previous research has speculated about the essential part that government policies provide in promoting innovation in the construction industry [31, 7].

Client's demand and acceptance incorporate the impact on how smart technologies are adopted in construction projects. Construction firms' inventive approach is frequently determined by the pressure encountered by their clients, who serve as investors and decision-makers. Despite the costs involved. Chen et al. [32] and Kineber et al. [33] highlight the significance of client demand as the main factor influencing the adoption of smart technology. Clients' acceptance relies on several variables, including perceived benefits, innovativeness, and confidence in the potential of smart technology. According to Chan et al. [32], client demand and satisfaction levels are influenced by the historical achievements of smart technology projects, such as timely completion and enhanced productivity. Thus, to boost adoption and investment in smart technology, construction firms are required to convey to their client the benefits of these technologies.

The effective integration of smart technologies in construction projects requires the support of top management. A key factor in delivering the required resources and establishing an atmosphere that is conducive to technology adoption is the dedication and support of top management. Ahmed et al. [34] and Lu and Deng [35] reaffirm that top management plays an essential part in promoting technology in construction firms. Top managers' willingness to adopt smart technology frequently hinges on how well they see the benefits and how they want to see the digital transformation work. Organisations that prioritise technology typically devote resources to policy restructuring and providing training programmes promoting technology adoption. The organization's willingness to adopt new technology is greatly influenced by the support of top management.

Proficiency in digital skills is essential for the effective adoption of smart technologies in construction projects. Project teams' ability to use smart technologies effectively impacts how broadly they are adopted. Yap et al. [36] and Ghobakhloo et al. [37] highlight the significance of technical expertise in implementing and managing smart technology. Firms must establish baseline capabilities and offer tailored training ensuring professionals are equipped with the right knowledge. Furthermore, continuous reskilling and upskilling are required to maintain the effectiveness of technology adoption and remain updated with advances in technology.

Promoting the application of smart technologies in construction requires stakeholders to have a solid understanding of technology. Encouraging the adoption of smart technologies requires raising awareness of their advantages, practicality, and applicability. According to Ejidike et al. [38], there are several stages involved in adopting technology. The first is awareness, which calls for constant acquisition of technological information. Enhancing knowledge and competence among project team members can be achieved through the creation of case studies that highlight successful applications of smart technology, as well as through training and seminars. As demonstrated by programmes like the Building Information Modelling (BIM) awareness campaigns in the UK, raising awareness among construction enterprises at all levels is essential to encouraging the adoption of smart practices. The following are the drivers noted in the reviewed literature:

- Government Policies
- Client Demand and Acceptance
- Top Management Support
- Technical Expertise
- Technology Awareness

2.4. Barriers to Adoption of Smart Technologies in the Construction Industry

Numerous research has highlighted several barriers that impact the adoption and implementation of smart technology within the construction industry. Organisational parameters are critical predictors of effective efforts [39]. According to Bajpai and Misra [40], the lack of managerial commitment significantly impacts eliminating barriers to adopting smart technology. Wong and

Lam [41] emphasised the need for top management support when enacting rules and ensuring self-discipline, emphasising that a major barrier is a lack of self-discipline. According to Lam et al. [42], the limitations to the practical deployment of ICT in construction project management were identified as being significant. These barriers included those related to information technology (IT) technical assistance and system absorptive capability in conveying information. Furthermore, an extensive amount of criticism has been engaged on the challenges involved in adopting smart technologies. Osunsanmi et al. [43] and Zhou et al. [44] emphasised the financial, economic, and practical challenges that the construction industry encounters despite the potential benefits of smart technologies. Additionally, Brewer et al. [45] contend that technological challenges are caused by high maintenance costs, inadequate technical experience among experts, and a lack of funding for research connected to construction. Comparably, Hosseini et al. [46] and Costin and Teizer [47] stressed the significant cost of acquiring, training, and adopting new technology in construction projects. Furthermore, Osunsanmi et al. [48] noted that the primary barriers to implementing smart technologies are the site-based nature of construction, uncertainty, and the complex nature of construction projects. Ojo et al. [49] added that protected monopolies, client willingness, professional complacencies, inadequate technological expertise, and a lack of government policies are some major barriers. They recommended achievable ideas, like training construction professionals to refresh their technological expertise, educating project owners about the value of smart construction to increase client willingness, and establishing and enforcing regulations that support smart technology in the construction industry.

- Lack of management commitment
- Lack of self-discipline
- Practical application of ICT
- Information transfer capabilities
- Cost implications
- Complex nature of construction projects
- Inadequate technological experience
- Clients' unwillingness
- Professional complacencies
- Protection monopolies
- Lack of government policies

3. Methodology

The research aim was to assess the drivers and barriers to the construction industry's adoption of smart technology by all project stakeholders. A structured questionnaire was employed to achieve the objectives set forth quantitatively. The three primary stages of the research approach were data collecting, data analysis, as well as results and discussions. The key reason why questionnaires were utilised is because they provide quick, simple, affordable, and effective means of gathering data. Following a methodical approach, papers containing the keywords "industry, adopting, smart, technologies, drivers, and barriers" were initially reviewed throughout the research process. There were three sections on the research questionnaire. The respondents' demographic data was provided in Section One. It included five items: years of experience, job description, work sector, educational background, and company size; drivers were covered in section two, and barriers to the construction industry's adoption of smart technology were covered in section three. This was accomplished by questioning the respondents' perceptions of the significance of these barriers and drivers. The questions reflected the barriers and drivers of smart technology found in the literature. The respondent was asked to rank the significance of each barrier on a 5-point Likert scale, with 1 signifying strongly disagree and 5 signifying strongly agree, for each question. A 5-point Likert scale was used for sections two and three due to its widespread application in the quantitative approach and the literature's stated reliability [50]. A Google form survey was developed and distributed by email and instant messaging applications. A pilot study was undertaken on a limited sample of participants who had previously completed the questionnaire. This made it easier to identify and rectify any errors or inconsistencies [51]. A group of highly educated construction experts participated in the pilot study. The Relative Importance Index was used to rank adopting smart technologies barriers in the questionnaire using the following equation:

$$RII = \frac{\sum w}{AN} \times 100\% \quad (1)$$

Where:
RII: the relative importance index
N: the total number of respondents
W: the weight given to each driver and barriers by the respondent.
A: Maximum weight (5)

The Relative Importance Index on participant responses determined the most significant barrier`s and drivers; when utilising the Likert scale was a suitable method for prioritising the drivers and barriers, making the method for ranking and comparing the drivers and the barriers simple.

4. Results and Discussion

A stratified random selection technique was used to distribute a total of 250 questionnaires, of which 195 were collected and deemed suitable for analysis following a validity check. This is considered realistic as it demonstrates a 78% response rate. Table 1 presents the number of questionnaires distributed and received.

Table 1. Analysis of Distributed Questionnaires

No of Questionnaires Distributed	No of Questionnaires Received	Percentage %
250	195	78

4.1 Personal Characteristics of Respondents

The data provided offers insights into the educational backgrounds, years of experience, types of organizations, job descriptions, and sizes of organizations among respondents in the construction industry. The respondents with bachelor's degrees represent the highest percentage of 28.7%, closely followed by those with higher diplomas at 28.2%. The distribution of advanced degrees among respondents appears to be well balanced, with master's degree holders accounting for 21.0% and PhD. holders at 22.1%, respectively. Regarding experience, a significant amount of respondents with 45.6% possess 6–10 years of experience, followed by respondents with less than 5 years of experience at 39.5% and those with 11–15 years of experience at 14.9%. This distribution indicates that a range of respondents to the survey includes experienced professionals and individuals at various stages of their professions. With 19.0% and 23.1% of responses, respectively, architectural firms and general contractors are the most common types of organisations in terms of organisational type. Significant percentages of government agencies, engineering firms, and consulting firms also show that various organisational types are represented in the construction industry. When considering job descriptions, engineers (Civil/ MEP) make up the largest group at 26.7%, closely followed by architects at 26.2%. Due to their varying positions within the construction industry, quantity surveyors, planning engineers, and project managers represent lower but still significant percentages of the respondents, with 23.1%, 14.4%, and 9.7%, respectively. Lastly, in terms of organisation size, the largest category consists of firms with fewer than 50 employees (28.2%), followed by firms with more than 1000 employees (16.9%). The distributions of the remaining size categories are rather balanced, suggesting that a mix of small, medium, and large organisations took part in the survey. Overall, the data presents an overview of a diverse set of respondents with a range of organisational, experience, educational, and occupational backgrounds in the construction industry. Table 2 presents the analysis of respondent’s profile. The graphical representations are also shown in the figures below.

Table 2: Respondent’s Profile

Level of education	**Frequency**	**Percent**
Bachelor’s degree	56	28.7
Higher Diploma	55	28.2
Master’s degree	41	21.0
PhD.	43	22.1
Year of experience		
11-15 years	29	14.9
6-10 years	89	45.6
Less than 5 years	77	39.5
Type of organization		
Architectural Firms	37	19.0
Construction Firms	31	15.9
Consulting Firms	22	11.3
General Contractor	45	23.1
Engineering Firms	21	10.8
Government Agencies	25	12.8
Real Estate Developer	5	2.60
Subcontractor	9	4.60
Job description		
Architect	45	26.2
Engineer (Civil/ MEP)	52	26.7
Planning engineer	28	14.4
Project manager	19	9.7

Quantity Surveyor	51	23.1
Organization's Size		
Below 50	55	28.2
100 – 500	20	10.3
50 – 100	33	16.9
500-100	33	16.9
500-1000	21	10.8
Over 1000	33	16.9

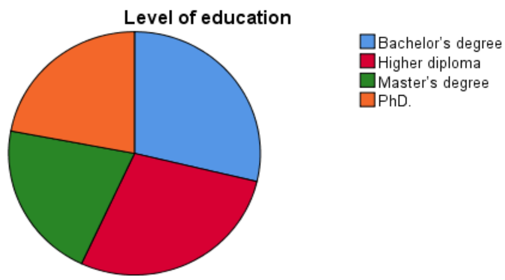

Figure 2. Respondent's Level Education

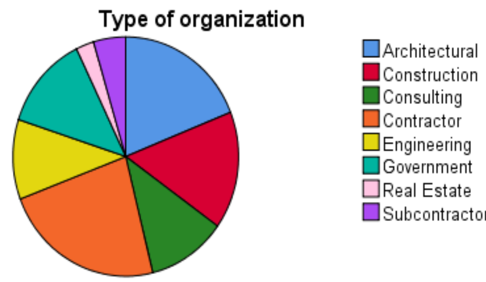

Figure 3. Respondent's Type of organization

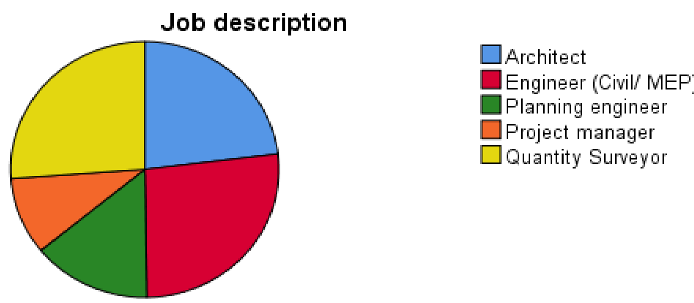

Figure 4. Respondent's Job Description

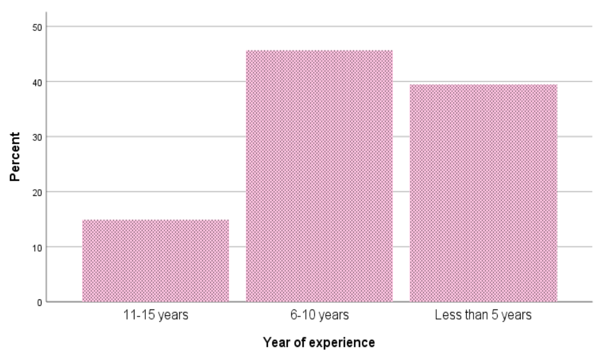

Figure 5. Respondent's Year of Experience

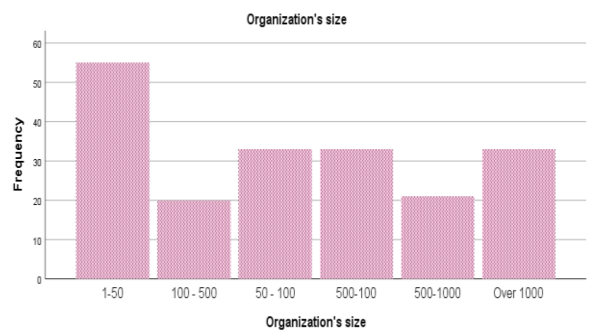

Figure 6. Respondent's Organization's Size

4.2. Drivers to adopting smart technologies in the Construction Industry

Analysing the Relative Importance Index (RII) and associated ranks of the drivers of smart technology adoption in the construction industry offers important insights into the key factors affecting technology adoption. Top management support has the greatest RII of 0.914, leading it to the top spot on the list. This emphasises the significance that leadership commitment and endorsement are to the success of technology adoption initiatives in construction firms. Technical expertise and clients' demand and acceptance, which secured the second and third places, respectively, are closely behind. The necessity of having skilled professionals capable of effectively integrating and managing smart technology is evidenced by a high RII of 0.912 for technical expertise. With an RII of 0.907, client demand and acceptance highlight the significance of client preferences and expectations in influencing the adoption of smart technology. Another significant factor is technology awareness, ranking at number four with an RII of 0.821. This highlights how crucial it is to educate construction stakeholders about smart technologies to encourage an innovative and adoptive culture. Government policies rank fifth on the list of drivers but have a slightly lower RII of 0.698. Although policies and initiatives from the government impact how smart technology is adopted, other factors like client demand and leadership support may have a greater overall effect. In conclusion, the analysis based on the RII and rankings emphasises the complexity of factors influencing the adoption of smart technologies in the construction industry. It also emphasises the role that supportive governmental policies, technical expertise, client engagement, leadership commitment, and technological awareness play in advancing technological innovation and advancement in the industry. The construction industry's drivers for adopting smart technology are analysed and shown in Table 3.

Table 3. Drivers to adopting smart technologies in the Construction Industry

Smart Technologies Drivers	Total	Total Number (∑W)	A*N	RII	Ranking
Top Management Support	195	891	975	0.914	1
Technical Expertise	195	889	975	0.912	2
Client Demand and Acceptance	195	884	975	0.907	3
Technology Awareness	195	800	975	0.821	4
Government Policies	195	681	975	0.698	5

4.3. Barriers to Adopting Smart Technologies in the Construction Industry

The Relative Importance Index (RII) and related ranks of smart technologies have been used to assess the barriers to their adoption in the construction industry. The complex nature of construction projects is at the forefront of these issues; with an RII of 0.989, it is ranked highest. This complexity includes a range of factors, such as stakeholder dynamics, project scale, and scope, and it poses significant barriers to the seamless adoption of smart technologies. The second rank is established by the lack of management commitment, which follows closely behind with an RII of 0.901. This demonstrates the significance of leadership support and buy-in to the advancement of effective technology adoption initiatives in the construction industry. Another significant barrier is information transfer capabilities, which rank third with an RII of 0.826. To fully realise the potential of smart technology, project stakeholders must engage in effective communication and data exchange. The necessity of providing construction professionals with the skills and knowledge they need to properly utilise smart technology is evidenced by the fact that inadequate technological experience stands at number four. Notable barriers that rank fifth and sixth, respectively, are clients' unwillingness and the lack of government policies. Establishing supportive regulatory frameworks and overcoming client unwillingness is critical to creating a setting favourable to adopting smart technology in the construction industry. The fact that other barriers like practical application of ICT, cost implications, professional complacencies, and protection monopolies occupy an intermediate rank in the middle position demonstrates their significance in impeding the broad adoption of smart technology. Finally, the RII and rank-based analysis highlight the complex barriers that construction encounters when adopting smart technology, highlighting the necessity of coordinated approaches and teamwork to effectively address these barriers. The analysis of the barriers to the construction industry's adoption of smart technology is shown in Table 4.

Table 4. Barriers to adopting smart technologies in the construction industry

Smart Technologies Barriers	Total	Total Number (∑W)	A*N	RII	Ranking
Complex nature of projects	195	964	975	0.989	1
Lack of management commitment	195	878	975	0.901	2
Information transfer capabilities	195	805	975	0.826	3
Inadequate technological experience	195	783	975	0.803	4
Clients' unwillingness	195	724	975	0.743	5
Lack of government policies	195	684	975	0.702	6
Practical application of ICT	195	619	975	0.635	7
Professional complacencies	195	592	975	0.607	8
Protection monopolies	195	557	975	0.571	9
Cost implications	195	553	975	0.567	10
Lack of self-discipline	195	516	975	0.529	11

4.4. Discussion

An understanding of the complex dynamics influencing technological innovation in the construction industry can be obtained by analysing the factors that encourage and hinder the adoption of smart technology in this industry. The vital role, factors like technical expertise, client demand, and top management support contribute to advancing technology adoption initiatives is highlighted by their high Relative Importance Index (RII) and top position. However, barriers like the complex nature of construction projects and lack of management commitment draw attention to the significant barriers that hinder widespread smart technology adoption. A multifaceted approach including stakeholder engagement, skill development, leadership endorsement, and supportive regulatory frameworks is required to address these barriers. Construction firms may leverage the transformative potential of smart technology to improve productivity, efficiency, and competitiveness in the market by identifying and efficiently addressing these barriers.

5. Conclusion

In conclusion, a range of factors, such as client demand, technical expertise, government policies, top management support, and technology awareness, contribute to the adoption of smart technologies in the construction industry. Widespread adoption is hindered by several barriers, including the complex nature of construction projects, lack of management commitment, and inadequate technological experience. Organisations must collaborate to create and promote regulatory frameworks, prioritise leadership commitment, invest in skill development, and improve client engagement to accomplish these barriers. Construction firms may increase productivity, efficiency, and industry competitiveness by effectively addressing these barriers while maximising the transformative potential of smart technologies.

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