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Adoption barriers to automation in the Saudi Arabian construction sector

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Abstract This paper explores the adoption barriers to automation in the Saudi Arabian's construction industry, from the perspectives of contractors, consultants, and owners. Eighteen barriers were uncovered through literature review and pilot-testing. A questionnaire survey was designed and presented to practitioners in the construction sector before distributing to the targeted professional. Ninety-five responses were analyzed utilizing the Relative Importance Index (RII). Cronbach's alpha tool was employed for examining the reliability of the collected data. The agreement level among the stakeholders was determined. The analysis shows that there is moderate agreement among the stakeholders. The top barriers of adopting automation are "High initial capital cost of automated equipment", "Shortage of fund in automation research and development", "Individuals' resistance to change", "Shortage of skilled workforce", "Lack of knowledge in automation applications". This research contributes to expand the boundaries of knowledge in the field of construction automation through presenting the barriers that should be taken into account by researchers and practitioners in developing countries, prior to implementing automation, so that future solutions can be investigated. The finding can benefit authorities in setting plans, developing strategies and introducing incentive programs to encourage the primary stakeholders in the construction industry to adopt automation.

Index Terms : automation adoption, barriers, Saudi Arabia, construction projects, project management

I. Introduction

Despite its significant contribution to the economy, the construction sector is troubled with inefficiencies and low productivity, shortcomings which can be addressed by robotics and automated systems when efficiently adopted [1]. The shortcomings are mostly related to quality, labor availability and safety, and project working conditions. Poor and declining productivity and risky working conditions represent challenges that cannot be addressed and solved by the current conventional construction and architectural industries [2]–[4].

According to McKinsey's Global Institute's report [5], the construction sector represents about %13 of the world Gross Domestic Product (GDP), with a total value of $10 trillion. Nevertheless, the industry has encountered severe challenges pertaining to cost, time, quality, and safety. Failure to meet project objectives and requirements can be attributed to a variety of reasons. Some reasons could include humans, who could be exposed to mistakes and errors especially in an industry that is full of complexities and uncertainties.

The idea of automation emerged from the concept of mechanization. Automation is defined as "the use of control systems and information technologies to reduce the need for human work in the production of goods and services" [6]. In construction, automation refers to the integration of methods, processes, and systems to improve productivity and increase machine autonomy in construction activities. Automation may involve the utilization of machinery, software, and digital technologies to perform tasks that were traditionally carried out manually by human workers. The main purposes of automation in the construction process are to increase productivity, improve performance efficiency, minimize site safety related issues, and ensure quality control and assurance throughout the construction process. However, adopting automation in the construction industry faces various barriers that deter its implementation. These barriers can significantly impact the efficiency, accuracy, and overall success of construction projects.

The construction sector accounts for 6.1% of the Saudi Arabian GDP [7] and employs 27.3% of the total workforce [8]. Despite these facts, the Saudi construction industry has encountered persistent challenges in achieving project objectives. Research has revealed extensive delays with average overruns exceedingly double the original contract duration, ranging from

2% to 172% [9]. The findings of the study highlight that low labor productivity ranks as the second most common cause of schedule delays.

Further, the construction sector has been encountering a scarcity of skilled workers, as noted by Al-Emad and Rahman [10]. Additionally, construction companies are encountering high expenses for workers, beyond basic salaries, including fees and health insurance. These challenges emphasize the urgency of introducing automation in contracting firms to align with the forthcoming phase.

I. A. Problem statement and research objectives

In Saudi Arabia, the concept of automation remains uncommon despite its widespread implementation in developed nations. Therefore, the objectives of this research are to (1) explore the status of automation adoption in the Saudi construction industry; and (2) determine the critical barriers hindering automation adoption in contracting organizations, from the viewpoints of contractors, consultants, and owners. The study aims to assist construction practitioners in addressing these hindering factors and providing a solid basis for understanding the status of automation implementation in the industry. Also, it can potentially assist governmental agencies in Saudi Arabia, in forming the needed legislation and regulations for facilitating the integration of automation practices within contracting firms. This aligns with the launching of the Saudi Vision 2030 in 2016, which has triggered a significant period of change in Saudi Arabia, prompting various entities, including those in the construction industry [11].

I. B. Research methodology

This study endeavours on highlighting the status of automation adoption in the local market of the Eastern province of Saudi Arabia, and determining the critical barriers hindering the automation adoption in contracting organizations, from the perspectives of contractors, consultants, and clients. The following steps outline the research methodology used to accomplish the stated goals:

- Conducting a thorough literature analysis to identify the primary barriers associated with the adoption of automation in the construction industry.
- Interviewing professionals in the construction industry to identify any additional barriers and to review the barriers identified from the literature.
- Designing a questionnaire survey to assess the importance of the adoption barriers including the barriers identified from the literature review and those proposed by local experts.
- Conducting a pilot study before distributing the questionnaire survey to the targeted professionals in the Eastern Province of Saudi Arabian. The pilot study involves consultation with experts to evaluate the effectiveness of the developed questionnaire survey.
- Distributing the questionnaire survey to the targeted professionals in the Eastern Province of Saudi Arabia.
- Applying Cronbach's alpha to measure the reliability and filtering the data.
- Measuring the importance level for the identified barriers using statistical analysis methods.
- Ranking each barrier according to the value of its Relative Importance Index (RII) and then quantifying the importance level of each barrier for contractors and consultants.
- Determining the agreement index among the stakeholders and draw conclusions and a set of recommendations.

II. Literature review

The adoption of automation in the construction industry has garnered interest in recent years due to the capabilities of automation to improve site production, safety, and efficiency [12]–[14]. Yet, several hindrances can prevent automation technology from being widely used for construction projects [15], [16]. Considerable previous research addresses the obstacles to automation adoption in the construction industry. This section aims to review the literature to identify the barriers to automation adoption in the construction industry.

Automation was introduced as a facilitator into the construction industry practices such as painting robots [17], earthmoving operations [18], [19], and steel-joints welding [20]. Like any industry, the global construction sector shares common driving forces with other industries and special ones on its own. Driving forces are the factors that shape organizations' decisions and strategies to maintain competitiveness. "Adoption of new technologies is driven by technology-push (new technologies that create new markets or offer improved methods for performing existing tasks), by demand-pull (market-pull or demand), or by a combination of both mechanisms" [21].

II. A. Driving forces to use automation in construction

The literature shows that a lot of research has been introduced to investigate automation adoption in the construction industry. Initial investment is found to be one of the main barriers of adopting automation in the construction industry [22]. Another barrier is the lake of knowledge required to adopt and utilize automation in the construction industry [23]. In another study conducted by Tafazzoli et al. [24], it has been found that adopting new technologies such as automation in construction faces fear of job displacement or concerns about job security. Yap et al. [25] stated that contracting company in construction suffer from inability of integrating different new technologies which lead to problems of inefficient use and compatibility concern. Further to the barriers stated above, the regulations can be another barrier that can prevent contracting companies of adopting automation and implementing automation in construction site [16]. Unlike manufacturing, where environments are more predictable and controlled, construction sites are subject to changing conditions, weather, and site-specific variables that make automation difficult to implement. Trujillo and Holt [15] emphasized that the unpredictable nature of construction environments is a major barrier to automation. The lack of awareness and understanding of the available automation technologies and their potential benefits is an additional barrier reported in the literature [16]. Economic instability and fluctuating market conditions can discourage investment in new technologies. Therefore, companies may be reluctant to invest in automation. This barrier is particularly relevant in regions with volatile economies, as discussed by Oke and Avboa [26].

It is well known that each construction project has unique characteristics and constraints that can complicate the implementation of automation. Factors such as project size, complexity, and location can affect the feasibility of using automated systems. Mahbub [27] highlighted that different construction areas have varying suitability for automation, making it challenging to adopt a one-size-fits-all approach. Clients and other stakeholders in construction projects may resist the adoption of automation due to concerns about costs, disruptions, and uncertainties related to new technologies. Convincing project owners to invest in automated solutions can be difficult, especially if the benefits are not immediately apparent. Trujillo and Holt [15] pointed out that client resistance is a notable barrier to the adoption of automation in construction. The lack of necessary infrastructure to support automation technologies can hinder their adoption. This includes not only physical infrastructure but also digital infrastructure such as reliable internet connectivity and advanced software systems. Studies by Delgado et al. [1] and Bello et al. [13] have indicated that inadequate infrastructure is a critical barrier to implementing automation in construction. There is often insufficient research and development (R&D) focused on automation in the construction industry. Limited investment in R&D can result in a lack of innovative solutions tailored to the specific needs of construction projects. Văduva-Șahhanoğlu et al. [28] stressed the importance of increased R&D efforts to overcome technological and human capital barriers. Integrating new automation technologies with existing construction processes and systems can be complex and resource intensive. This integration often requires significant changes to workflows, training programs, and management practices, which can be daunting for many companies.

Văduva-Șahhanoğlu et al. [28] demonstrated the essential need for the construction sector to be automated. To accomplish this goal, the study reviewed the economic and political perspectives associated with the construction industry. Delgado et al. [1] investigated the adoption barriers to automation and robotics in the UK construction industry. The study involved 28 experts to examine the challenges that were categorized into four classes and ordered in terms of relative importance. These include factors of "contractors-economic", "client-economic", "technical and work-culture", and "weak business case". The results revealed a lack of strong correlation among the identified factors. Oke and Avboa [26] studied the influencing drivers for automation adaption in the AEC industry of South Africa. The top five drivers ranked in sequence, emerged as follows: "Training and site implementation of automation", "Change of attitude in construction companies", "Implementation of new IT and telecommunication technologies", "Manufacturing modular components" and "Frequent use of robots and automated machines", "problems of acceptance in the construction industry" and "not enough improvement in economy".

Mahbub [27] investigated the barriers facing the construction sectors of Australia, Japan, and Malaysia in employing automation and robotics technologies. The study identified 8 barriers, which were analyzed in terms of their frequency occurrence. The top three barriers were "different construction areas usage", "the high cost of automation and robotics" and "the fragmented nature of the construction industry". Trujillo and Holt [15] investigated the causes behind low adoption of automation in the construction industry. These causes included lack of unknown technologies to the industry, uncontrolled construction sites, lack of software tools that could process work on complex environments, the difficulty of convincing owners to adopt the use of automated tools and the fact that most available technologies are just prototypes. The study emphasized that the construction industry should be more proactive towards accepting automation and robotics and study the available barriers, which are more culturally based, rather than technically based.

Regona et al. [23] reviewed the causes of the limited adoption of artificial intelligence (AI) in construction. The study focused on the challenges of adoption AI in project lifecycle, including the planning, design, and construction phases. The study concluded that the fragmented nature of the construction industry is the main reason that hinders the acceptance AI tools in construction. The study also revealed that construction projects could benefit more from AI at planning stage to save cost and time at the construction stage. Flechsig et al. [14] identified the barriers and best practices for the implementation of robotic process automation. The study revealed 25 barriers, classified under three categories, namely technical, organizational, and environmental. The study concluded that the implementation depends on the readiness of the organizations' digital procurement.

Feldmann [16] identified the barriers of employing automation and robotics in modular construction (MC). The study utilized a qualitative approach to identify the barrier from eight manufacturers of MC in Switzerland, Germany, and Austria. The study uncovered seven different barriers. These included IT-related, economical, ecological, technical, social, process-related, and regulatory barriers. The study concluded with recommendations to improve the adoption of implementing automation and robotics in MC. In addition to identifying the barriers that hinder construction automation, the application of digital technologies such as cloud computing has also been studied in recent years, which could potentially facilitate automation in construction. Bello et al. [13] investigated the utilization of cloud computing in the construction industry. The study revealed that the utilization of cloud computing in the construction domain is an emerging research area, which could potentially add value to the construction domain.

II. B. Adoption barriers to automation in the construction sector

Fifteen major barriers were determined from the literature review, and adopted in this current study, as presented in Table 1. These barriers are described as follows:

Table 1: Initial list of barriers affecting automation in the construction industry

No.	Barriers	Source					
		[1]	[4]	[27]	[28]	[29]	[30]
B1	Individuals' resistance to change	✓			✓	✓	✓
B2	The shortage of skilled workforce	✓			✓	✓	
B3	High initial capital cost of automated equipment	✓			✓	✓	
B4	Low rate of return	✓	✓				
B5	The sufficiency of the current productivity rates	✓					
B6	Shortage of funds in research and development	✓	✓			✓	
B7	Lack of local manufacturers				✓		
B8	Unproved effectiveness of automated equipment	✓					
B9	The requirement of training	✓	✓		✓	✓	
B10	Difficulty of involving automation in the current work procedures				✓		
B11	The fragmentary nature of the construction industry			✓		✓	✓
B12	Culture and human factor			✓		✓	✓
B13	Absence of large-scale and repetitive opportunities					✓	✓
B14	Lack of competition						✓
B15	Lack of knowledge of automation applications					✓	

II. B. 1) Individuals' resistance to change

In general, people tend to resist and fear any change.

II. B. 2) Shortage of skilled workforce

The availability of skilled technical operators and information suppliers is very crucial to the successful implementation of automation in construction. In the absence of such personnel, automation is unattainable.

II. B. 3) High initial capital cost of automated equipment

Contracting firms usually encounter difficulties with project cash flow, due to several reasons such as delayed payments, poor management, among others. Therefore, securing project funding is a major concern for contractors and as a result, allocating part of the fund to adopt automation can be considered a challenge.

II. B. 4) Low rate of return

Despite the high initial cost of investment in automated equipment, adopting automation requires a long period of time, or a large number of projects in order to reach the breakeven point and recover the initial invested capital when compared with traditional methods.

II. B. 5) The sufficiency of the current productivity rates

The concept of automation has been initiated to overcome current construction issues including poor productivity rates, quality, and occupational safety. If the current production rates are sufficient and project objectives are achievable, there will be no incentive to adopt automation.

II. B. 6) Shortage of fund in research and development

Automation relies on research and development (R&D) efforts. Contracting firms allocate minimal attention to this domain. R&D aisre not limited to developing machines, but also includes conducting a benefit analysis of opportunities and follow-up developments by assigning employees to perform those tasks.

II. B. 7) Lack of local manufacturers

Lack of available suppliers and manufacturers of automated machines in local markets makes the decision on adopting automation difficult. The availability of spare parts and immediate technical support is very crucial to contractors. Additionally, the procurement processes can be complex and time-consuming.

II. B. 8) Unproved effectiveness of automated equipment

It has been claimed that automation improves the contractors' capabilities towards achieving better performance. Contractors still have no trust in automation and technology, especially in the initial stages.

II. B. 9) The requirement of training

Successful implementation of automation requires continuous improvements and training of personnel. Such initiatives require significant time and cost.

II. B. 10) Difficulty of involving automation in the current workflow

The current work practices might appear convenient for the contractor. Introducing modification in the current, traditional work method could hinder the workflow.

II. B. 11) Fragmentary nature of the construction industry

Contractors' choices to implement automation are influenced by pre-construction procedures, which encompass contracting processes. For instance, in a design-bid-build project, design and construction take place sequentially by separate entities. This could lead to construction designs that are not compatible and may hinder the feasibility of automation adoption. Thus, automation requires a high degree of process integration and the involvement of all stakeholders right from the project's outset.

II. B. 12) Culture and human factor

Labor organizations remain deeply concerned about the implications of increasing automation, which could potentially replace human labor.

II. B. 13) Absence of large-scale and repetitive opportunities

Adopting new technologies and automation might not be economically feasible, if there is not a strong demand for their advanced features, especially when implemented in smaller projects. However, when the quantity of large-scale projects increases, the possibilities of adapting automated techniques increase, due to the potential cost savings that could be realized.

II. B. 14) Lack of competition

Normally, contractors continuously improve their skills to stay in business and achieve project objectives. However, contractors might lose the motivation when there is weak competition.

II. B. 15) Lack of knowledge of automation applications

Numerous automation techniques have been developed and applied worldwide. However, contractors might not be aware of certain efficient technologies. Moreover, contractors might also lack knowledge about suppliers and procurement procedures.

III. Data collection and analysis

The barriers were assessed through a 5 points Likert scale, where; 1 = "totally unimportant", 2 = "not important", 3 = "neural", and 4= "important" and 5 = "very important". The questionnaire was provided in two languages; English and Arabic, to aid in comprehending the questions. A pilot-testing was conducted, to adjust the identified barriers to the local market and assess the clarity of the developed survey. The pilot-testing was performed by three experts prior to the distribution of the survey to the entire sample size, to rectify any deficiencies. The outcome of the pilot-testing resulted in adding three barriers: (1) no such requirements by clients; (2) lack of incentives; and (3) lack of knowledge on the benefits of automation (profits, environmental issues, timesaving and so on), while no barriers were eliminated during the pilot-testing, resulting in a final count of 18 barriers.

In addition to construction clients, the intended respondents encompassed construction professionals, who are directly involved in contracting and project management firms, and consulting offices. A total of 148 questionnaires were distributed. Ninety-five were collected and confirmed as suitable for analysis. This yields a response rate of about 64%, which is a sufficient figure for the study's purposes. The breakdown of the responses included 30 consultants, 30 clients, and 35 construction professionals. According to Hassanain et al. [31], a sample size of 30 respondents from each respondent's group is deemed satisfactory for approximating a normally distributed data set, that accurately represents the border population.

It should be noted that the reliability analysis is one of the essential concepts that take into account the consistency of measurements and results [32]. Accordingly, the reliability of the responses in this study was examined, upon calculating the

Cronbach's alpha coefficient, to measure the internal consistency of the questionnaire items. This coefficient value ranges from 0.00 to 1.00. An adequate reliability of the respondent is typically demonstrated through a coefficient value of 0.70 or more [33]. The coefficient alpha (α) is an estimate of the variance proportion which is consistent in a set of the questionnaire responses. This estimation is calculated using the following equation, as outlined by Vaske et al. [34]:

$$a=\frac{N}{N-1}\left(\frac{\sigma_x^2-\sum_{i=1}^{N}\sigma_{yi}^2}{\sigma_x^2}\right), \tag{1}$$

where, N is the number of questionnaire items on a scale; σ_x^2 is the variance of the observed total score, and σ_{yi}^2 is the variance of item i for respondent y.

The "Relative Importance Index" (RII) technique was employed to assess and rank the barriers to the adoption of automation in construction. The reason behind the adoption of the RII is due to its simplicity and its capability to quantify the measure of importance and to rank the importance of each barrier within the study. This will allow decision makers to understand the key drivers influencing automation barriers and focus on the most influential factors that significantly impact the outcomes or performance of a particular process. The RII of each barrier was calculated using the following equation:

$$RII=\left(\frac{\sum SR}{W\times N}\right), \tag{2}$$

where, SR is the scale of each factor collected from the survey; W is the highest value of the weight, which is equal to 4 in this study; and N is the number of the study participants.

The assessment of the statistical correlations between the different views obtained through the Likert response format is determined through comparing the rankings of the responses [33]. Therefore, the level of agreement degree between two different groups of interest was measured using Spearman's rank correlation coefficient [35]. The values of Spearman's Rank Correlation coefficient range from -1.00 to +1.00, where +1.00 reflects a full agreement between the two analyzed groups, while -1.00 reflects full disagreement. Table 2 shows the levels of agreement definitions for the determined value of the Spearman's coefficient of rank correlation (p) [36].

Table 2: Profile of the respondents

Category	Classification	Frequency	Percentage
Years of experience	1 - 3 years	34	36%
	4 - 6 years	29	30%
	7 - 9 years	12	13%
	10 - 12 years	11	12%
	More than 12 years	9	9%
Current position	General manager	5	5%
	Project manager	18	19%
	Construction manager	1	1%
	Department head	7	7%
	Senior engineer	4	4%
	Engineer / Project engineer	52	55%
	Other	8	9%
Educational level	PhD	1	1%
	Master	32	34%
	Bachelor	60	63%
	Diploma	2	2%
Educational background	Civil engineering	45	47%
	Architectural engineering	10	10%
	Mechanical engineering	10	11%
	Electrical engineering	16	17%
	Other	14	15%
Company type	Contractor	35	36%
	Consultant	30	32%
	Owner	30	32%

The Spearman's rank correlation coefficient was calculated using the following equation:

$$p=1-\frac{6\sum d^2}{n(n^2-1)}, \tag{3}$$

where, P is the Spearman's Rank Correlation coefficient; d is the difference between two rankings; and n is the count of measured variables.

The interpretation of Spearman's coefficient of rank correlation can be described as follows [36]:

- A coefficient between 0.1 and 0.3 indicates a low level of agreement.
- A coefficient between 0.3 and 0.5 indicates a moderate level of agreement.
- A coefficient between 0.5 and 0.7 indicates a moderate to high level of agreement.
- A coefficient between 0.7 and 1 indicates a high level of agreement

IV. Results

The final questionnaire was distributed digitally through Google Forms. A total of 104 responses were collected. However, 9 responses were eliminated due to different reasons; 5 of which had conflicting answers, while the rest displayed uniform scores all barriers. Hence, a refined group of 95 respondents was considered for the final analysis.

IV. A. Respondents' characteristics

Table 2 indicated that respondents hold degrees in Civil, Architectural, Mechanical and Electrical engineering, occupying various positions such as general manager, project manager, construction manager, and department head. A portion (21%) of the respondents has experience of more than 10 years in the construction industry, of which about 32% of them holding a master's degree. The participants have been involved, and in certain cases have led to several organizational changes. About 35% of the organizations are contractors, 30% are consultants, and the remaining are owners. Evidently, the participants are well experienced in the local market, hence they are deemed to be a source of information on the status of the local construction market. Consequently, the information gathered from such competencies supports the reliability of the findings.

IV. B. Status of automation adoption

The respondents were requested to consider only the project's execution phase when answering the questions. The results revealed that 68 of the construction professionals indicated that their organizations have not adopted any form of automation during the past ten years. In the current timeframe, automation adoption has shown a significant increase, with 62 professionals claiming that their organizations have introduced some form of automation. Additionally, the count increased to 79 professionals, who indicated that their organizations intend to incorporate automation within the next three years.

The current forms of automation in use involved GIS, GPS, and topographical measures, as indicated by 36% of the total respondents. Machine-related practices came second, by 30%, while monitoring and controlling related-activities was ranked third, by 24% of the total respondents. Finishing works was the lowest to experience automation as per 10% of the respondents. Further, the majority of project types to employ automation are engineering projects, commonly referred to as industrial construction, as indicated by 74 respondents. Building and highway projects had nearly equivalent frequencies, standing at 58 and 57, respectively. Thus, it can be inferred that all types of projects require the implementation of automation in order to meet the project requirements.

IV. C. Barriers to automation adoption in Saudi Arabia

The purpose of analyzing the barriers of automation adoption in construction is to have an insight into the critical barriers from the perspectives of the contractors, consultants, and owners. Ninety-five responses were received from various construction industry professionals in Saudi Arabia. Among those responses, there were 35 contractors, 30 consultants, and 30 owners. The RII values, ranks, and $C\alpha$ values of the data received from the respondents are illustrated in Table 3. Table 4 shows a comparison of the ranking of the barriers for the three's perspectives.

The level of agreement was determined through calculating the Spearman's Rank Correlation coefficient between contractors and consultants, contractors and owners, and consultants and owners. Table 5 shows the level of agreement among the three stakeholders. This indicates that the level of agreement among the practitioners is moderate.

Table 3 indicates that the six top barriers, associated with the automation adoption in construction, are as follows:

- The high initial capital cost of automated equipment.
- Shortage of funds for automation research and development.
- Individuals' resistance to change.
- Shortage of skilled workforce (operators and technicians who are capable of working with automated equipment.
- Lack of knowledge in automation applications.
- The potentially required training.

V. Discussion and recommendations

As depicted in Table 4, the "high initial capital cost of automated equipment" emerges as the most dominant barrier of adopting automation in construction industry in Saudi Arabia. It is ranked in the top six barriers for contractors, owners, and consultants. These findings align with the finding suggested by [1], [27], [37]. This high significance of this barrier stems from the fact that construction organizations consider the minimization of costs as a major priority. Given that financial resources are a critical factor affecting the adoption of construction automation, the promotion of such technologies cannot be achieved without allocating enough financial support [29]. Therefore, allocating funds for purchasing automated equipment can be very costly compared to the cost of handling similar work using the current practices.

Table 3: Ranking of the barriers based on the viewpoints of all respondents

Barriers	Importance Level				Total Responses	RII(%)	Rank
	Totally Unimportant	Not Important	Important	Very Important			
High initial capital cost of automated equipment	1	10	36	48	95	84.5	1
Shortage of funds for automation research and development	3	5	41	46	95	84.2	2
Individuals' resistance to change	0	14	41	40	95	81.8	3
Shortage of skilled workforce (operators and technicians who are capable of working with automated equipment)	1	15	36	43	95	81.8	3
Lack of knowledge about automation applications	1	12	42	40	95	81.8	3
The potentially required training	2	13	39	41	95	81.3	6
Lack of knowledge about the benefits of automation (profits, environmental issues, time-saving)	1	15	46	33	95	79.2	7
Lack of local manufacturers (suppliers of such equipment)	5	17	33	40	95	78.4	8
No requirements by clients	7	16	39	33	95	75.8	9
Lack of incentives to use automation	6	18	41	30	95	75.0	10
Absence of large-scale and repetitive opportunities	8	17	42	28	95	73.7	11
Lack of competition	9	20	34	32	95	73.4	12
The fragmentary nature of construction industry	6	24	38	27	95	72.6	13
Low rate of return (on automation investments)	7	21	46	21	95	71.3	14
Difficulty of incorporating automation in the current work procedures	8	23	45	19	95	69.7	15
Unproven effectiveness of automated equipment	9	27	35	24	95	69.5	16
Sufficiency of current productivity rates	6	28	44	17	95	68.9	17
Cultural and human factors	7	31	39	18	95	67.9	18
$C\alpha = 0.851$							

Table 4: Comparing the ranking of the barriers for the three's perspectives

Barriers	Contractors		Consultants		Owner	
	RII (%)	Rank	RII (%)	Rank	RII (%)	Rank
The potentially required training	89.3	1	73.3	5	80.0	10
Individuals' resistance to change	87.9	2	75.8	3	80.8	8
High initial capital cost of automated equipment	87.9	2	80.8	1	84.2%	5
Lack of knowledge about automation applications	87.9	2	73.3	5	83.3	6
Shortage of fund for automation research and development	86.4	5	80.0	2	85.8	1
Shortage of skilled workforce (operators and technicians who are capable of working with automated equipment)	85.7	6	75.0	4	84.2	4
Lack of local manufacturers (suppliers of such equipment)	82.1	7	67.5	13	85.0	3
Lack of knowledge on the benefits of automation (profits, environmental issues, time-saving....)	80.0	8	71.7	10	85.8	1
Difficulty of incorporating automation in current work procedures	76.4	9	60.8	17	70.8	17
No requirements by clients	75.7	10	69.2	11	82.3	7
Absence of large-scale and repetitive opportunities	74.3	11	67.5	14	79.2	11
Lack of incentives to use automation	74.3	12	71.7	7	79.2	12
Cultural and human factors	72.9	13	60.8	18	69.2	18
The fragmentary nature of construction industry	72.1	14	71.7	7	74.2	15
Lack of competition	71.4	15	68.3	12	80.8	8
Unproven effectiveness of automated equipment	70.7	16	65.0	15	72.3	16
Sufficiency of current productivity rates	70.0	17	61.7	16	75.0	14
Low rate of return (on automation investments)	65.0	18	71.7	7	78.3	13

Table 5: The level of agreement among the three stakeholders

Stakeholders	Contractor	Consultants	Owner
Contractor	1	0.433823529	0.398529412
Consultants		1	0.382352941
Owner			1

The "shortage of funds for automation research and development" has a considerable effect on preventing the implementation of automation in the construction industry of Saudi Arabia. This barrier was ranked among the top three challenges based on all viewpoints. This finding is in agreement with that of [1], [38], [39]. This suggests that there is a lack of support to research in this domain, due to the shortage of the allocated funds.

The "potentially required training" is another critical barrier hindering the adoption of construction automation. It was ranked among the top five barriers based on the perceptions of contractors and consultants. This finding agrees with that of [1], [2]. Training of construction workers requires a considerable amount of cost and time, to facilitate the successful achievement of construction automation. As a result, many construction firms might be hesitant to allocate portions of their budgets to train their employees on operating automated construction equipment, since minimizing the direct and indirect costs of the firms remains a key consideration for decision-makers at the top management level.

Furthermore, the cultural perspective has also a significant impact on the adoption of construction automation. Changing the perspectives of the construction stakeholders on this barrier is generally difficult and requires more countermeasures [30]. The "individuals' resistance to change" is another significant barrier associated with adopting automation in construction [1], [40]. It is ranked as the second barrier hindering construction automation, according to the viewpoints of contractors and consultants, respectively. This is because practitioners display resistance and apprehension towards any new changes within the construction industry. They feel that introducing new technologies may result in the loss of some employees' jobs and render the expertise of certain professionals obsolete.

The "shortage of skilled workforce" appears as a critical barrier affecting the implementation of automation. The viewpoints of all respondents show that it is among the top four barriers. These findings emphasize the barrier of a skilled workforce in facilitating technological advancements in construction [41].

Finally, the lack of knowledge about new technologies, associated with a field, plays a vital role in influencing the adoption of such developments in local practices. The "lack of knowledge about automation applications", is a notable barrier that illustrates the limited awareness of many construction firms about construction automation applications and their associated benefits. This finding agrees with the study of [12].

As recommendation to reduce "the shortage of funds for automation and development", the government can take the followings steps: increase funding allocating to research and development of automation; implementing tax incentives for companies investing in automation research and implementation; provide grants to companies investing in automation research; provide research grants; provide training to individuals in automation and education programs; Collaborative Research Initiatives; Regulatory Support; Offer support to for establishing clear regulatory frameworks that promote innovation while ensuring safety and ethical standards are met can create a conducive environment for automation R&D investments; improve the quality of education provided in schools and universities. The government can implement several strategies: investing in education and skill development programs that align with industry needs, ensuring a workforce that is already prepared for available jobs. promoting public-private partnerships which can help to create tailored training programs that meet specific employer requirements.

VI. Conclusion

This study demonstrates the importance of identifying the automation adopting barrier in construction industry in Saudi Arabian. The study stated that despite its widespread application in various developed countries, this concept remains uncommon in Saudi Arabia. The study identified the most significant barriers to adopting automation from the perspectives of contractors, consultants, and owners. The identification of such barriers could assist decision-makers and professionals at the upper management level of construction firms to develop measures to facilitate automation adoption within the local industry. The findings of this study can also be beneficial by local authority to set plan, put strategy and introduce incentive program to encourage construction main stakeholder to adopt automation in construction industry. The study is limited to the Eastern Province of Saudi Arabian and limited to surveys and interviews as data collection tools. The data interpretation is based on the adoption of a relatively important index which may affect the validity and reliability of the findings. The study does not consider automation adoption in construction industry in oil and gas projects.

Data availability statement

The data that support the findings of this study are available upon request.

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Conflict of interest

The authors declare no conflict of interest

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