Assessing the Factors Affecting the Use of the Precast Concrete Systems in Saudi Arabia Based on Stakeholders Survey

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Abstract
The construction industry in Saudi Arabia (SA) is improving and growing rapidly. The use of precast concrete systems (PCS) proposes numerous advantages such as rapid construction, high-quality construction, sustainability, and efficient associated costs, which are all aligned with the Saudi Arabia 2030 vision. These advantages could be the most important factors in deciding to use PCS as a construction system. However, other factors could adversely affect the use of PCS in SA. These factors are not identified in the existing literature and this study addresses this gap. The study investigates the factors affecting the use of PCS in SA. These factors are identified through an online industry survey, and 171 responses were recorded from various stakeholders. The results present the positive and negative factors affecting the use of PCS in SA from the industry perspective. Recommendations are proposed to overcome the negative factors and increase the use of PCS in SA.

Keywords Precast concrete system · Saudi Arabia · Survey · Usage factors

1 Introduction
The construction industry in Saudi Arabia (SA) is improving and growing rapidly. Despite the challenges faced due to the COVID-19 pandemic, the industry is expected to grow by 5% each year for the next 5 years [1]. It is still the largest sector receiving investment in SA with more than USD 825 billion worth of planned and un-awarded projects [2, 3]. With this large expansion and growth in the industry, the demand to construct new buildings has increased efficiency. Accordingly, new construction systems were proposed in the market to overcome the disadvantages of other systems, as well as to cover the large demand for buildings. The precast concrete system (PCS), which is considered a type of industrialized building systems (IBS), has been offered in the market [4]. There is a good opportunity for the precast system to get a big share of the market against the traditional construction systems, i.e. cast in situ. In 2020, the global precast market share was 114.78 billion USD, and it increased to 118.48 in 2021. It is expected to grow at a rate of 4.4–5.5% to reach a 159.85 billion USD in 2028 due to the large demand on construction [5]. The biggest market will be infrastructure followed by commercial buildings. The precast market has grown in the USA from 17.4 to 17.9 billion USD and it is expected to grow at a rate of 5.5% annually [6]. In Saudi Arabia, construction contracts have grown from 22 to 75 billion USD from 2020 to 2021 which evidences the construction demands that is expected to grow massively in the coming years [1].

To date, there is no universal definition commonly used for IBS. Other authors may use the term offsite or prefabricated instead of IBS [7]. [8] classified IBS as “a system in which concrete components prefabricated at sites or in factories, are assembled to form structures under strict quality control and minimum in situ construction activity”. Also, IBS can be defined as to build with elements or components that are prefabricated at the factory under a controlled environment with
standardized shapes and dimensions, and then transported to the site to be assembled there [4, 9].

Generally, PCS offers several advantages such as faster construction, higher quality, reduced construction waste, and lower cost compared to other traditional construction systems [10, 11]. These advantages could be the most important factors in choosing PCS as a construction system in SA. However, other factors such as unwillingness to change to new systems, the aesthetic image of precast, limitation on the design of the precast system, and the limitation of transportation of the precast elements could have an adverse influence on the use of PCS in the industry [12]. To overcome these factors, it is firstly important to define and identify them in any given location.

Identification of factors affecting the use of PCS in the construction industry for different locations has been studied in several previous studies. For example, in the USA, lack of academic education regarding PCS and transportation restrictions were found to be the most dominant factors which limit the use of PCS [13]. In addition, several additional factors affect the use of PCS. According to the previous studies [13–20], the following 13 factors are the most significant factors that affect the use of the PCS: demand for large projects/housing projects, level of standardization, experts, design issues, transportation, union/governmental politics, communication among parties, user satisfaction, buildability, quality, speed of erection, sustainability, and cost saving. These studies are discussed in detail in Sect. 2.1.

The factors that affect the use of PCS in SA are not significantly known and a gap is observed in the existing literature. The significance of this study is that it identifies and presents the factors affecting the use of the PCS in SA, which will aid in the decision making process for owners, consultants, and contractors of SA to select the best construction system that suit their needs. The study also considers the perception of the precast concrete manufacturers in the country for improving understanding of the perfect use for the system. Lastly, the study paves the way for future research work regarding precast concrete use in the SA construction industry as presented in Sect. 4. The objectives of this study are as follows:

- Identify/investigate the factors affecting the use of the PCS in SA.
- Study these factors and their effect on the use of the PCS as a construction system.
- Provide recommendations to enhance the use of the PCS in SA.

2 Research methodology

This section of the study discusses the survey development, survey distribution, and results in analysis. The research methodology is summarized as per the following main steps:

1) Identifying the most common and relevant factors that affect the adoption of the PCS based on the literature review
2) Questionnaire survey design
3) Population and sample size determination
4) Data analysis method

All of the four steps are discussed in detail in the following sections.

2.1 Identifying the Factors

Several studies exist in the literature that has identified the factors in different locations around the world. For example, [13] surveyed the factors affecting the use of the PCS in the USA, and he compared to the finding of the previous study done in 2000 by [14]. In [13] work all of the factors were evaluated to find the changes that happened to the precast sector in the USA during 11 years from 1995 to 2006. The main factors are level of standardization, expertise, design issues, transportation, union politics, communication among parties, cost savings, and user satisfaction.

In addition, Arditi Ergin et al. [14] explored the factors that hindered the PCS from being used in the USA by mail surveys. Surveys were sent to 100 contractors, 100 design firms, 100 precast concrete manufacturers, and 100 local labour unions. It was found that the construction market in the USA satisfied almost all of the provisions for the extensive use of industrialized building systems. However, different factors were negatively affecting the use of the PCS in the USA such as the shortage of experts in precast. In addition, the engineering curriculum in the USA did not provide enough education about precast and industrialized building systems. Many contractors were not aware of the capabilities of precast systems, and they did not know the advantages of using the PCS. [14] conducted his research on 11 main factors that were affecting the use of the PCS in the USA, and the effect of each factor was evaluated using a questionnaire survey, which was mailed to contractors, design firms, and precast concrete manufacturers, and local labour unions. Questions were tailored based on the addressed entity, i.e. contractor, designer, or manufacturer. The 11 main factors were:

- Demand for large projects
- Government-funded projects
- The level of standardization
- Expertise
Furthermore, [21] conducted a study to evaluate the factors that prevented the extensive use of PCSs in Turkey and the USA. He performed a comparison between the factors that controlled the extensive use of PCSs in Turkey and the USA. In Turkey, it was not clear what factors were mainly controlling the use of precast systems, whereas in the USA the survey participants said that size and load restrictions on transportation of precast elements, poor communication among parties, and lack of qualified contractors specialized in PCSs were limiting the extensive use of the PCS. Similarly, additional studies have highlighted several different factors which affect the use of precast concrete [13–20, 22].

In summary, multiple factors were identified in different locations. These factors are primarily influenced by the state of the construction industry in each location. Generally, the factors are similar and affect each other; however, differences in the factors are observed from one location to another. For example, [21] is a study that identified the factors in Turkey and the USA and found no conclusive factors for Turkey; however, a list of factors was identified for the USA. Similarly, the factors for SA should be identified; however, no study exists in current literature targeting the construction industry of SA and this study fills this gap. Furthermore, the factors from these existing studies were mapped onto a matrix to identify the major factors identified in all the studies combined (Table 1). This resulted in the identification of the thirteen following major factors that influence the use of PCs and thus are used in this study:

1. Demand for large housing projects
2. Level of standardization
3. Expert
4. Design issues
5. Transportation
6. Union/governmental politics
7. Communication among parties
8. Buildability
9. User satisfaction
10. Environment
11. Cost saving
12. Future
13. Speed of erection

2.2 Questionnaire Survey Design

The affecting factors, listed in the questionnaire, were selected and prepared based on the extensive literature review. One to four questions were developed under each factor to allow for measuring how each factor is affecting the use of PCSs in SA either positively or negatively. The questionnaire was formed of four main parts as follows:

1) Part 1—Introduction Question: Participants were asked to define the field where they were working either owner/client, consultant, contractor, or precast manufacturer.
2) Part 2—Personal/General Information: Participants were asked to provide general information such as years of experience, company classification, and size of the business from the financial point of view.
3) Part 3—Questionnaire Main Body: Participants were asked to evaluate the 13 factors by answering the questions under each factor, a total of 34 questions. The evaluation was based on a rating from one to five.
4) Part 4—Participate in The Result: In this optional part of the questionnaire, participants were asked to list any additional factors where they believe that was affecting the use of PCSs in SA and it was not listed above. Moreover, they were asked to give their mobile number and email ID, in case they would like to know the result of the questionnaire. Fortunately, many of the respondents holding top management positions such as CEOs and VPs provide their contacts, which means that they were interested in the topic.

A pilot study was conducted to ensure that the questionnaire is well prepared and easy to be understood by the respondent and there were no deficiencies in the content, and to get feedback from the experts. The questionnaire of this study was distributed to four experts under each field client, consultant, contractor, and precast manufacturers. A valuable expert’s feedback was collected and considered to prepare the final version of the questionnaire.

2.3 Population and Sample Size Determination

The population of this study includes owners, consultants, contractors, and precast manufacturers operating within the SA. There are around 25 precast concrete manufacturers in SA that provide complete precast systems including columns, beams, slabs, and cladding. However, only 10 were considered because they were approved by relevant authorities. A similar number was considered in determining the sample size of the owners, since there is no reference number for the total number of owners in SA. However, owners and consultants who operate projects with less than SR7 million were
eliminated in the analysis stage. On the other hand, there were around 293 contractors classified as grades 1 and 2 as per the Ministry of Municipality and Rural Affairs (MOMRA) in SA. In addition, according to MOMRA, there were 292 consultants’ offices classified under Architectural/Civil consultants in SA. It must be mentioned that participants with experience of fewer than 5 years were excluded during the analysis stage. However, people in high managerial positions such as chief executive officer (CEO), chief operating officer (COO), vice president (VP), and senior managers, participated in filling the questionnaire. Respondents from the targeted companies provided adequate, reliable information about the factors affecting the use of the PCS in SA. The project type is restricted to large buildings excluding industrial and infrastructure projects. The representative sample size of the study was calculated using the following formula [23].

\[
\begin{align*}
    n_0 &= \frac{Z^2 \cdot pq}{SEM^2} \\
    n &= \frac{n_0}{1 + \frac{n_0}{N}}
\end{align*}
\]

where \((n_0)\) The first estimated sample size \((p)\) The proportion of characteristics measured in the population. It is expressed by decimal equals 0.5, which reflects that the maximum sample size is 50% of the population \((Z)\) Area under the normal curve. (1.440 for a confidence interval of 85%) \((q)\) \((1 - p)\), which is 0.5 \((SEM)\) The maximum allowed standard error. In this study, it is considered ± 10% \((n)\) The final estimated sample size \((N)\) The targeted population sizes

Using the Kish equation, \(n_0\) equals 23 responses from the inter-population owners, consultants, contractors, and precast manufacturers. The final estimated sample size for them was as follows:

For owners/clients:

\[
    n = \frac{n_0}{1 + \frac{n_0}{N}} = \frac{23}{1 + \frac{23}{23}} = 11.5 \approx 12 \text{ responses}
\]

For consultants:

\[
    n = \frac{n_0}{1 + \frac{n_0}{N}} = \frac{23}{1 + \frac{23}{292}} = 21.3 \approx 21 \text{ responses}
\]

For contractors:

\[
    n = \frac{n_0}{1 + \frac{n_0}{N}} = \frac{23}{1 + \frac{23}{293}} = 21.3 \approx 21 \text{ responses}
\]

For precast concrete manufacturers:

\[
    n = \frac{n_0}{1 + \frac{n_0}{N}} = \frac{23}{1 + \frac{23}{25}} = 11.9 \approx 12 \text{ responses}
\]

The questionnaire link was sent to 100 owners, 126 consultants, 126 contractors, and 50 precast manufacturers. One reminder was sent to all participants, and two reminders were sent to respondents holding top management positions such as CEOs and VPs. Almost 350 of the participants viewed the link, but around 171 filled out the questionnaire. Table 2 shows the respondent’s rates.

It is worth mentioning that the number of total valid responses increases the importance of the study. Among the
Table 2 Response rates of surveys

| Type of recipient                     | Sent | Wrong address | Required sample size | Answered | Eliminated | Net number of valid answers | Rate of valid response mailed % |
|--------------------------------------|------|---------------|---------------------|----------|------------|-----------------------------|-------------------------------|
| Owner/client                         | 100  | 7             | 12                  | 31       | 7          | 24                          | 24%                           |
| Engineering/consultant firm          | 126  | 21            | 62                  | 17       | 45         |                             | 35%                           |
| Contractor                           | 126  | 21            | 45                  | 5        | 40         |                             | 32%                           |
| Precast manufacturer company         | 50   | 12            | 33                  | 2        | 31         |                             | 62%                           |
| Total                                | 402  | 7             | 66                  | 171      | 31         | 140                         | 34%                           |

total number of participants, only 140 were approved to be included in the study, due to the following participants’ elimination rules:

1) Owners operating projects with less than SR7 million
2) Consultants who operate projects with less than SR7 million
3) Contractors of grade 3 and below
4) Participants with less than 5 years of experience
5) Participants with irrelevant positions
6) Misconception filling

The strict conditions and the aforementioned acceptance rules of this study eliminate some of the participants’ data; finally, the total number of the accepted participants was 140 among all owners, consultants, contractors, and manufacturers who have adequate experience working in SA.

2.4 Data Analysis Method

The main critical prime factors affecting the use of PCS were identified using statistical analysis techniques. The 5-point ranking system was used to evaluate the collected data. Participants were asked to evaluate the factors by giving them a number 1 to 5 as to how much they agree/disagree with the statement that related to the specific factor, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. In the questionnaire, there were around three questions to represent the effects of each factor to evaluate its effects on the use of the PCS. The weighted average of the results is then calculated to identify the agreement index for each factor. The agreement index is based on the following ranges:

1) To 1.80 = Strongly disagree
2) 1.81 to 2.60 = Disagree
3) 2.61 to 3.40 = Neutral
4) 3.41 to 4.20 = Agree
5) 4.21 to 5.00 = Strongly agree

3 Results and Discussion

It is important to understand the current usage of PCS in the SA construction market before addressing the factors. The participants were asked to evaluate the statement: The PCSs are widely used in Saudi Arabia. Results show that it cannot be concluded that the PCSs are widely used in SA, even though a considerable number of responses agreed that it was widely used (Fig. 1). Therefore, it can be concluded that the precast market is promising and there is a big chance for enhancement and investment.

Next, the data of the 140 valid responses were studied, analysed, investigated, and discussed. The positive and negative impacts of the factors on the use of the precast system were also investigated and discussed. Then the responses of each group were analysed separately and collectively to find
the most significant nine factors among the 13 factors. These factors were selected based on the P-value with an 85% confidence level. Table 3 summarizes the main findings regarding the agreement index on positive/negative impacts of each of the factors on the use of PCS. It can be concluded that the PCS to some extent is commonly used in SA, and it is a promising market where 66% of the participants stated that the use of the PCS will be increasing within the next 10 years. There are different factors affecting the use of PCS in SA. Some factors have positive impacts, while others have a negative impact on its use. There is a huge demand for housing projects. There is also a good infrastructure that supports the growth of PCS in terms of developing new and existing roads and precast companies. The positive impact of the PCS is understood in terms of cost savings, constructability, and environmental interest. However, other factors such as transportation and design issues are negative and need to be overcome to promote the use of PCS. The nine factors are discussed in detail in the following sections.

3.1 Demand for Large Housing Projects

As the demand for large projects/housing projects increases, the use of PCS increases [13]. Massive housing project demands supported by the government [24] create an ideal environment for the usage of PCS effectively, continuously, and economically.

Two statements were developed to cover the impact of housing projects on the use of PCS. The first question was

- As the demand for large housing projects increases, the need for precast concrete buildings increases.
- It is preferred to use the PCS in large housing projects, where the buildings are standardized.

From the results, it can be concluded that the relation between the demand for large housing projects and the use of PCS is very positive. 66% of the participants believe that as the demand for large housing projects increases, the use of precast concrete buildings increases. The large housing projects generate an ideal environment where PCS can be utilized. Moreover, 83% consider that the best use of PCS is in large housing projects, where the buildings are standardized.

3.2 Level of Standardization

Having the same shapes/sizes of precast concrete elements among the precast concrete manufacturers is considered a major advantage of selecting PCS as a construction system [13]. This simplifies designers’ work during the design stage by selecting the suitable precast elements/members from the standard shapes/sizes available in the market. As long as the precast manufacturers produce the same standard shapes and sizes of precast elements, the usage of PCS becomes increasingly popular. Owners and contractors need to have the free choice of selecting any of the precast manufacturers to produce their building without changing or substituting any of the precast element that was initially designed. However, in some cases, this standardization might limit and restrict the use of PCS, where a special or unique shape is required. This forces the precast manufacturer to build new moulds to accommodate for new shapes and results in an extra cost added to the project cost accordingly.

In this regard, participants were asked whether precast concrete manufacturers in SA have the same standard shapes and sizes of precast concrete elements. The results showed that the agreement index of this question was 2.88 which was in the Neutral range. Around 37% of the participants stated that precast concrete manufacturers in SA did not have the same standard shapes and sizes of precast concrete elements, which affected the use of PCS negatively. This is an expected result of a weak communication/coordination between owners, consultants, and contractors from one side, and precast manufacturers from the other side, which restricts the use of PCS and shall be counted as a negative point against the use of PCS.

3.3 Experts

Lack of experts in precast technique is investigated and identified. Lack of structural, architectural engineers having experience in precast systems, lack of skilled labours, and lack of contractors having prior experience with PCS all limit the use of PCS [13–15, 21, 25]. The relation between the experts’ availability and the use of PCS is positive, i.e. as the number of experts increases the use of PCS increases. Lack of expertise leads to poor design, poor production, and poor erection/management activities, and eventually, owners will be discouraged to go with such a system.

To explore the level of expertise at PCS availability in both consultations and contracting levels, the following two questions were addressed:

- Consultants in SA have adequate technical/engineering experience in PCSs.
- Contractors in SA have adequate technical/engineering experience in PCSs.

To have reliable answers without any biased answers, consultants’ responses were eliminated in analysing the first question, while contractors’ responses were eliminated in the second question.

Table 3 shows that there is a lack of expertise in PCS at both consultants’ and contractors’ parties, since around
Table 3 Summary of the main findings of the survey

| Factors                              | Variables                                                                 | Evaluation terms | Mean response | Agreement index |
|--------------------------------------|---------------------------------------------------------------------------|------------------|---------------|-----------------|
| Demand for large housing projects    | As the demand of large housing projects increases, the need for precast concrete buildings increases | 10 9 30 40 51    | 3.81          | Agree           |
|                                      | It is preferred to use precast concrete system in large housing projects, where the buildings are standardized | 9 3 9 45 74      | 4.23          | Strongly agree  |
| Level of standardization             | Precast concrete manufacturers in Saudi Arabia have the same standard shapes and sizes of precast concrete elements | 14 38 46 35 7    | 2.88          | Neutral         |
| Experts                              | Consultants in SA have adequate technical/engineering experience in PCS | 12 32 41 47 8    | 3.05          | Neutral         |
|                                      | Contractors in SA have adequate technical/engineering experience in PCS | 7 26 50 51 6     | 3.16          | Neutral         |
| Design issues                        | Structural capability is limited with the use of precast concrete system   | 18 52 31 29 10   | 2.72          | Neutral         |
|                                      | Precast concrete buildings are not suited to resist earthquake forces       | 26 54 33 17 10   | 2.51          | Disagree        |
|                                      | Architectural creativity suffers when Precast concrete systems are used     | 11 45 26 39 19   | 3.07          | Neutral         |
| Transportation                       | It is easy to transport the precast concrete elements anywhere in the SA    | 6 28 35 42 29    | 3.43          | Agree           |
|                                      | Transportation constraints limit the design of precast concrete elements in terms of shape and size | 6 21 29 64 20    | 3.51          | Agree           |
|                                      | The transportation cost is one of the main concerns for choosing the precast concrete system as a construction system | 4 29 37 49 21    | 3.39          | Neutral         |
| Communication among parties          | Manufacturers in Saudi Arabia are involved at the early design stage of a precast concrete building | 8 31 34 55 12    | 3.23          | Neutral         |
|                                      | Contractors in Saudi Arabia purchase from the same precast concrete manufacturers who are consulted at estimation/bidding stage | 7 35 61 35 2     | 2.93          | Neutral         |
|                                      | Precast concrete manufacturers in Saudi Arabia manage their production, transportation and erection activities in a professional way | 4 16 50 53 17    | 3.45          | Agree           |
|                                      | Precast concrete manufacturers give the required technical/engineering support for contractors and consultants | 4 11 45 62 18    | 3.56          | Agree           |
| Buildability                         | The execution of a precast concrete building involves less activities compared to the traditional system | 3 8 21 67 42     | 4.00          | Agree           |
| Environment                          | PCS is environment-friendly                                               | 1 0 38 59 42     | 4.01          | Agree           |
| Cost savings                         | The use of precast concrete system reduces the overall project cost (i.e. engineering, materials, supervision, labour cost, etc.) | 8 20 46 49 17    | 3.34          | Neutral         |
30% of the participants, with an agreement index of 3 out 5, reported that they disagree or strongly disagree. Even though around 37% of the participants agreed on both statements, this percentage is still low and not sufficient to conclude that there is a satisfactory number of experts in PCS.

Accordingly, more care should be taken to increase the number of experts in either contractors’ or consultants’ offices. This can be achieved through educating practitioners and reaching out to the precast companies. However, the responses to these two questions are promising since a considerable number of participants believe that there is an adequate number of expertise in PCS.

Figures 2 and 3 show the breakdown results of the aforementioned two questions regarding the technical and engineering experience in PCS of the SA market. The two figures indicate that both consultants and contractors do not present the actual situation of the PCS experience available in the SA construction market, as both of them tend to give a positive view of their experience, but when their responses were eliminated it showed a lack of experience in the Saudi market.

### 3.4 Design Issues

There are different concerns when it comes to the design (structural and architectural) of PCS. Even though the structural analysis of the PCS is somehow similar to the ordinary/traditional cast in situ system, there are considerable differences when it comes to the design of connections in PCS. Moreover, all of the production/construction stages of the precast concrete elements shall be considered in the design such as demoulding, transportation, erection, and after erection stages, where these stages do not exist in the cast in situ concrete. Furthermore, one of the main design concerns of using the PCS is the structural capability of the PCS in resisting seismic forces [26]. This concern draws more attention while designing PCS in areas with high seismic activities. The design of the precast connections to resist high seismic forces should be taken into consideration to avoid severe collapses. However, nowadays the structural capability of PCS is much more enhanced, and additional care of elements connections develop to withstand high seismic forces [21]. Similarly, the building codes are significantly changed to account for the precast connection design under seismic loads [27, 28].

To assess the structural capability of PCS and to evaluate the level of market knowledge, the following two questions were presented to be evaluated by participants:

- Structural capability is limited with the use of PCS
- Precast concrete buildings are not suited to resist earthquake forces.

The result of these questions shows a good awareness level of the structural capability of PCS as around 50% of the participants disagree with the first statement, while 57% of the participants disagree with the second statement. Accordingly, it is concluded that the participants are aware of the structural capability of PCS, and they are updated with the last issued codes and standards. The values presented in Table 3 conclude that most of the contractors and consultants are aware of the structural capabilities of PCS.

On the other hand, when it comes to the architectural design of PCS the authors found different opinions about this subject. Some architects claim that the architectural creativity suffers when PCS is used, while the other believes that the PCS can be a great help in constructing the complex patterns with high quality that cannot be produced by other traditional systems [21]. Figure 4 shows examples of different complex patterns which were achieved by using PCS in SA.
For a better understanding of how this issue is affecting the use of PCS, participants were asked to state how much they agree with the statement says: Architectural creativity suffers when PCSs are used. The results in Table 3 emphasize the fact that there were mixed opinions about how PCS affects architectural design either positively or negatively, since it shows that 40% (56 of 140) believe that architectural creativity is not suffering when PCSs are used, while 41% (58 of 140) believe that it does.

In this regard, it can be concluded that in some cases the architectural ingenuity is enhanced when PCSs are used, while in the other cases it is not. This is depending on the nature of the building and the design concept that needs to be achieved. In addition, nine of the responding precast manufacturers agreed that the architectural creativity suffers when PCS are used, which means that there are some real concerns about the architectural creativity of using PCS.

3.5 Transportation

Transporting the precast elements to the site is one of the processes involved in the execution of a precast building. Any issues in transportation lead to negative effects on the use of PCS [21, 25]. There are different constraints in transporting precast elements in SA such as the maximum allowed load on the truck and the maximum available length of the trucks [29]. These constrain to make the transportation limitations important and must be considered in designing and selecting the PCS as a construction system. Keeping in mind that PCS is preferred to be used for buildings/bridges with special long span beams, the weight and length of the precast elements become large, 50 tons for weight and 30 m in length, which exceed the capacity/limits of the standard sizes of trucks as per the ministry of transportation [29]. Accordingly transporting such large items requires special trucks, which cost more.

As a result, the design of a PCS in some cases is controlled by transportation constraints. In this regard, participants were asked whether it is easy to transport precast elements in SA. Table 3 shows that around 51% of the participants believe that it is easy to transport the precast element across SA, while only 24% disagree with this. The majority believes that there are no governmental limitations that restrict the transportation of precast concrete elements across SA.

Furthermore, to know the consequence of the transportation limitations on the design activities and the cost of using PCS, the participants were asked to rank how likely they agree/disagree with the following questions:

- Transportation constraints limit the design of precast concrete elements in terms of shape and size.
The transportation cost is one of the main concerns for choosing the PCS as a construction system.

Results show that 60% (84 out of 140) of the participants, 20 of the 31 precast manufacturers, believe that the design of PCS is limited/restricted by the transportation constraints, which is considered as a negative impact on the use of the PCS in SA. In addition, 50% of the participants believe that the transportation cost of PCS should be considered in selecting a construction system, which means the cost of transportation is relatively high and may be considered as a barrier of selecting the PCS as a favourable construction system, which affects the use of PCS in SA negatively.

### 3.6 Communication Among Parties

One of the main advantages of using PCS is the speed of construction (erection) that reduces the project cost. However, in some cases, a delay in erection and productions’ schedule might occur, and consequently, project cost increases [21]. This is an expected result of a poor communication and/or coordination between consultants, contractors, and precast manufacturers. Good communication and proper coordination among the project parties reduce the problems and enhance the project progress. These problems may appear at different stages of the project or after the project is completed, and resolving these problems requires rework activities that are so expensive. In the precast concrete field, the parties start communicating at early stages “design stage”, as it results in a better implementation of a PCS [21].

To address this, two questions were presented to the participants during different project stages. First, participants were asked at what level they agree that consultants in SA get the precast manufacturers involved at the early design stage of a precast concrete building.

Results highlight that around 48% (67 out 140) of the participants are agreeing/strongly agreeing that consultants involve the precast concrete manufacturers at the early design stage of a precast concrete building, which enhances the use of PCS and leads to successful implementation of the precast technique. On the other side, there are around 27% of the participants disagree/strongly disagree with the statement. This percentage is relatively high and should not be ignored, because it is considered as a barrier to the successful implementation of the precast technique. Consultants shall enhance their coordination and involvement of the precast concrete manufacturers at the early design stage of a precast concrete building.

Moreover, purchasing from the same factory that was consulted at estimation/design stage enhances the implementation of the PCS [13, 14], since fewer compatibility problems may appear which require fewer coordination activities between the contractor and precast manufacturers as well. Accordingly, participants were asked whether contractors in SA purchase from the same precast concrete manufacturers who is consulted at estimation/bidding stage.

30% (42 of 140) of the participants believe that contractors did not purchase from the same manufacturers who were consulted at estimation/bidding stage. The participants’ score an average of 2.9 out of 5 between disagree and neutral, which means that contractors tend not to purchase from the same manufacturers in many cases, however, they might sometimes do. This is in line with the fact that contractors consult with more experienced manufacturers during estimation/bidding stage, while they purchase from the manufacturers of the lowest price; consequently, this gives more chances of compatibility problems to occur. This behaviour of the contractor justifies the result, where 43% (61 of 140) the participants have the neutral approach to this issue.

Finally, two general questions were introduced regarding this subject to ensure that the subject is covered properly. The two questions were:

- Precast concrete manufacturers in SA manage their production, transportation, and erection activities in a professional way.
- Precast concrete manufacturers give the required technical/engineering support for contractors and consultants.

The result of these two questions shows that precast concrete manufacturers operating in SA are capable and eligible to run the precast business. However, there is a chance for enhancement, and this can be concluded from the number of the participants whom are selected to be neutral. To ensure that the result is unbiased, Fig. 5 represents the results without the responses of precast concrete manufacturers to have reliable answers.

### 3.7 Buildability/Constructability

The use of the PCS enhances the buildability/constructability when compared to the traditional construction system “cast in situ”, because fewer site activities are required in construction [25]. Lowering the site activities results in less working hours, less coordination on site, less supervision needed, and less cost accordingly.

It is found that 78% (109 of 140) of the participants believe that the execution of a precast concrete building involves fewer activities compared to the traditional system. In conclusion, the buildability factor positively affects the use of PCS; so, it should be considered as an easier to build system in comparison with the traditional system.
3.8 Environment

The environment becomes an increasing concern due to the threat of climate change, especially in SA. SA Vision 2030 vision aims to manage SA finances efficiently and effectively. It plays a big role in directing the construction industry to select and use new construction systems that are more economical, efficient, durable, and environmentally friendly [30]. The PCS is considered to be an environment-friendly technique.

In this regard, participants were asked to provide their opinion about how much the PCS is environment-friendly, where the question is: Is PCS environment-friendly? It is found that 72% of the participants either agree or strongly agree that the PCS is environmentally friendly; see Table 3. While 27% were neutral, only one stated that he strongly disagreed that PCS is environmentally friendly. Accordingly, the environmental factor is considered a positive factor that affects the use of PCS positively.

3.9 Cost Savings

Cost is one of the biggest concerns in the construction field when a construction system is under investigation to be selected. [21] claimed that the use of PCS in a project lowered the overall project cost. In fact, this is not always true and it is subjected to the nature of the building and its needs. According to interviewed experts in the SA construction industry, using PCS in a building that required beams with large spans would lower the overall project cost, and similarly, a building that requires complex architectural patterns using the PCS reduces the cost as well. On the other hand, the use of PCS for regular traditional buildings that are not repetitive increases the overall project cost.

This is seen in the results where 33% of the participants are neutral regarding the cost reduction when PCS is used. However, 47% of the participants believe that the use of PCS reduces the overall project cost (i.e. engineering, materials, supervision, labour cost, etc.). In conclusion, the cost-saving factor positively affects the use of PCS; so, it should be considered in choosing PCS as a construction system in comparison with the traditional system, especially for specific buildings such as buildings with large spans.

4 Conclusions

Saudi Arabia’s Vision 2030 revitalized the construction industry, especially housing and infrastructure development. Recently, the construction industry called for an increase in turnover of the prefabricated buildings market in Saudi Arabia which witnessed noticeable demand for low- to mid-rise residential buildings, project homes, and public housing. Contrary to stand-alone units, apartments and townhouse units’ price has increased by 17% and 11.7% in Riyadh and Jeddah in the third quartile of 2021. Therefore, low-to mid-rise residential buildings attracts developers that find prefabricated construction very attractive to investment due to cost-effective and time-efficient. In this study, the factors affecting the use of PCSs in SA have been studied, investigated, and evaluated. Firstly, factors that affect the use of PCS were identified from the literature review, and then, the most significant nine factors among the collected factors were selected to be studied and discussed. The data were collected through a questionnaire survey that was sent via e-mail to more than 400 participants, while around 171 responses were received. However, among the total number of participants, only 140 were accepted to be involved in the study due to the
restricted elimination rules. It can be concluded that the positive impact of the PCS in SA is understood in terms of cost savings, constructability, and environmental interest. On the other hand, other factors such as transportation and design issues are negative and need to be overcome to promote the use of PCS.

To enhance the use of PCS and to get the maximum of its advantages, the positive factors should be enhanced and the negative factors should be minimized and eliminated eventually. Adopting protocols and educating practitioners in the PCS industry will spread awareness among different parties concerning their roles and liabilities in the PCS technology which will lead to better coordination and eliminate most of the problems developed from miscommunication. The following are further recommendations to the construction industry of SA that can potentially increase the use of PCS:

1. Precast concrete manufacturers should coordinate with each other regarding the issue of standardizing the precast level; they should reach the maximum level of standardizing the sizes of the common precast elements such as Hollow Core, I-beams, double TT slab, and other elements if possible.

2. Consultants and contractors are advised to recruit architectural and structural engineers who are experts in the PCS.

3. Precast concrete manufacturers should enhance their products, especially cladding techniques to satisfy the complex architectural needs.

4. Precast concrete manufacturers should look deeply to the issue of transportation in a matter of cost and design limitation. Alternative and creative solutions should be adopted.

5. Contractors are advised to procure from the same precast concrete manufacturers who were consulted at estimation/bidding stage.

This study identified the critical factors and their impact on the use of PCS in the construction industry of SA. After the identification of factors, future research work in the area is enabled and recommended to further enhance the use of PCS in SA construction industry. For example, a recent study explored the benefits, barriers, and opportunities of using building information modelling (BIM) to advance PCS in Australia [31]. Although the use of BIM in SA is still in its infancy [32], similar work should be conducted to identify the potential use of BIM among the different stakeholders in the industry and to support the transformation of the industry to adopt BIM and PCS.

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Declarations

Conflict of interest The authors declare no conflict of interest.

References

1. Mordor Intelligence: Saudi Arabia Construction Market Size, Report (2022 - 27 j). (2022)
2. Ahmed, W.; Asif, M.; Alrashed, F.: Application of building performance simulation to design energy-efficient homes: case study from Saudi Arabia, Sustainability 11, 6048 (2019). https://doi.org/10.3390/su11216048
3. Ahmed, W.; Asif, M.: A critical review of energy retrofitting trends in residential buildings with particular focus on the GCC countries. Renew. Sustain. Energy Rev. 144, 111000 (2021). https://doi.org/10.1016/j.rser.2021.111000
4. Badir, Y.F.; Kadir, M.R.A.; Hashim, A.H.: Industrialized building systems construction in Malaysia. J. Archit. Eng. 8, 19–23 (2002). https://doi.org/10.1061/(ASCE)1076-0431(2002)8:1(19)
5. Fortune Business Insight: Precast Concrete Market Size, Growth & Industry Trends [2028]. (2021)
6. Grand view research: Precast Concrete Market Size | Industry Report, 2021–2028. (2021)
7. Anuar, K.; Kamar, M.; Hamid, Z.A.; Nor, M.; Azman, A.; Sanusi, M.; Ahamad, S.: Industrialized building system (IBS): revisiting issues of definition and classification. Int. J. Emerg. Sci. 1, 120–132 (2011)
8. Trikha, D.N.: Industrialized building systems: prospects in Malaysia. Google Search. In: Proceedings World Engineering Congress (1999)
9. Anuar Mohamad Kamar, K., Alshawi, M., Abd Hamid, Z.: Barriers to industrialized building system (IBS): the case of Malaysia. In: BuHu 9th International postgraduate research conference (IPGRC 2009). Salford (2009)
10. Wasim, M.; Vaz.Serra, P.; Ngo, T.D.: Design for manufacturing and assembly for sustainable, quick and cost-effective prefabricated construction—a review. Int J Constr Manag (2020). https://doi.org/10.1080/15623599.2020.1837720
11. Tam, V.W.Y.; Hao, J.J.L.: Prefabrication as a mean of minimizing construction waste on site. Int. J. Constr. Manag. 14, 113–121 (2014). https://doi.org/10.1080/15623599.2014.899129
12. Wong, P.S.P.; Whelan, B.; Holdsworth, S.: Are contractors ready for greater use of prefabrication in projects? An empirical analysis on the role of unlearning and counter-knowledge. Int J Constr Manag (2018). https://doi.org/10.1080/15623599.2018.1539160
13. Polat, G.: Factors affecting the use of precast concrete systems in the United States. J. Constr. Eng. Manag. 134, 169–178 (2008). https://doi.org/10.1061/(ASCE)0733-9364(2008)134:3(169)
14. Arditii, D.; Ergin, U.; Günhan, S.: Factors affecting the use of precast concrete systems. J. Archit. Eng. 6, 79–86 (2000). https://doi.org/10.1061/(ASCE)1076-0431(2000)6:3(79)
15. Jiang, L.; Li, Z.; Li, L.; Gao, Y.: Constraints on the promotion of prefabricated construction in China. Sustainability 10, 2516 (2018). https://doi.org/10.3390/su10072516
16. Akmam Syed Zakaria, S.; Gajendran, T.; Rose, T.; Brewer, G.: Contextual, structural and behavioural factors influencing the adoption of industrialised building systems: a review. Archit Eng Des Manag 14, 3–26 (2018). https://doi.org/10.1080/17452007.2017.1291410
17. Idrus, N.J.B.: Construction related factors influencing the adoption of industrial floor systems. Constr. Manag. Econ. 20, 13–19 (2002). https://doi.org/10.1080/01446190110101218
18. Daget, Y.; Zhang, H.: Evaluation of experts’ preferences for selection of suitable industrialized building systems. In: Lim, C.W. and Zhu, X. (eds.) MATEC Web of Conferences. p. 6., Paris (2018)
19. Daget, Y.T.; Zhang, H.: Decision-making for evaluation and selection of suitable industrialized housing system. Int J Geomat. 15, 167–173 (2018). https://doi.org/10.21660/2018.50
20. Kaya, T.; Phatsaphan, C.; Peansupap, V.: Identification of significant factors impacting precast utilization in Cambodia construction industry. Eng. J. Res. Dev. 30(1), 15–32 (2019)
21. Polat, G.: Precast concrete systems in developing vs. industrialized countries. J. Civ. Eng. Manag. 16, 85–94 (2010). https://doi.org/10.3846/jcem.2010.08
22. Wu, G.; Yang, R.; Li, L.; Bi, X.; Liu, B.; Li, S.; Zhou, S.: Factors influencing the application of prefabricated construction in China: from perspectives of technology promotion and cleaner production. J. Clean. Prod. 219, 753–762 (2019). https://doi.org/10.1016/j.jclepro.2019.02.110
23. Kish, L.: Survey sampling, Revised Wiley, Hobroken (1995)
24. Alqahtany, A.: Affordable housing in Saudi Arabia’s vision 2030: new developments and new challenges. Int. J. Hous. Mark. Anal. 14, 243–256 (2021). https://doi.org/10.1108/IJHMA-04-2020-0035/FULL/PDF
25. Glass, J.; Pepper, C.: Perceptions of precast concrete cladding in the UK market. Archit. Eng. Des. Manag. 1, 233–246 (2005). https://doi.org/10.1080/17452007.2005.9684595
26. Priestley, M.J.N.; Tao, J.R.: Seismic response of precast prestressed concrete frames with partially debonded tendons. PCI J. 38, 58–69 (1993)
27. Yamashita, R.; Sanders, D.H.: Seismic performance of precast unbonded prestressed concrete columns. ACI Struct. J. 106, 821–830 (2009)
28. Ghosh, S.K.: Significant changes from the 2011 to the 2014 edition of ACI 318. PCI J 61, 56–80 (2016)
29. MOT: Road regulations and rules, https://www.mot.gov.sa/en/Roads/RoadRegulations/Pages/default.aspx
30. Government of Saudi Arabia: Saudi Arabia Vision 2030. (2016)
31. Mostafa, S.; Kim, K.P.; Tam, V.W.Y.; Rahnamayiezekavat, P.: Exploring the status, benefits, barriers and opportunities of using BIM for advancing prefabrication practice. Int. J. Constr. Manag. 20, 146–156 (2020). https://doi.org/10.1080/15623599.2018.1484555
32. Ahmed, W.; Asif, M.: BIM-based techno-economic assessment of energy retrofitting residential buildings in hot humid climate. Energy Build. (2020). https://doi.org/10.1016/j.enbuild.2020.110406

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