วิศวกรรมสารฉบับวิจัยและพัฒนา
Engineering Journal of Research and Development
วิศวกรรมสถานแห่งประเทศไทย ในพระบรมราชูปถัมภ์
The Engineering Institute of Thailand under H.M. The King's Patronage
ปีที่ 30 ฉบับที่ 1 มกราคม-มีนาคม 2562
Volume 30 Issue 1 January-March 2019
Received 4 April 2018
Revised 9 May 2018
Accepted 18 May 2018 Physical Sciences

IDENTIFICATION OF SIGNIFICANT FACTORS IMPACTING PRECAST UTILIZATION IN CAMBODIA CONSTRUCTION INDUSTRY

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ABSTRACT

Among all construction methods, precast construction has gained its popularity over the past 50 years due to the realized benefits. However, it is surprising that the uptake of precast construction method is still in its infancy in Cambodia. Thus, the goal of the research aims to investigate the factors impacting precast utilization in Cambodia construction industry by evaluating the significance of 5 benefits and 25 hindrances obtained from extensive literature reviews which impact the practitioner's perspectives via a closed-ended questionnaire of four different groups such as designers, manufacturers, deliverers, and assemblers. Consequently, this applied cross-sectional quantitative research found out top five significant factors in four main processes such as design, production, transportation and assembly of precast technology in Cambodia construction industry.

KEYWORDS: Cambodia, Construction industry, Significant factors, Precast

บทคัดย่อ

การก่อสร้างระบบชิ้นส่วนคอนกรีตสำเร็จรูปเป็นวิธีการก่อสร้างที่ได้รับความนิยมเพิ่มขึ้นอย่างต่อเนื่องในช่วง 50 ปีที่ผ่านมา โดยมีสาเหตุหลักจากข้อดีของการก่อสร้างระบบดังกล่าว อย่างไรก็ตาม การก่อสร้างระบบชิ้นส่วนคอนกรีตสำเร็จรูปยังอยู่ในระยะเริ่มต้นในประเทศกัมพูชา ดังนั้น งานวิจัยนี้จึงมีวัตถุประสงค์หลักในการสำรวจปัจจัยที่ส่งผลกระทบต่อการใช้ชิ้นส่วนคอนกรีตสำเร็จรูปในอุตสาหกรรมก่อสร้างของกัมพูชา โดยทำการประเมินจากข้อดีจำนวน 5 ข้อ และอุปสรรคจำนวน 25 ข้อ ที่ได้จากการทบทวนวรรณกรรม ผ่านแบบสอบถามในมุมมองของผู้ปฏิบัติงานที่เกี่ยวข้องใน 4 ขั้นตอนหลัก ได้แก่ ผู้ออกแบบ ผู้ผลิต ผู้ขนส่ง และผู้ติดตั้งชิ้นส่วนคอนกรีตสำเร็จรูป ซึ่งผลการศึกษาจะแสดงถึงปัจจัยสำคัญ 5 ปัจจัยแรกของแต่ละขั้นตอนหลัก ซึ่งส่งผลกระทบต่อการใช้ชิ้นส่วนคอนกรีตสำเร็จรูปในอุตสาหกรรมก่อสร้างของกัมพูชา

คำสำคัญ: กัมพูชา, อุตสาหกรรมก่อสร้าง, ปัจจัยสำคัญ, ชิ้นส่วนคอนกรีตสำเร็จรูป

1. Introduction

Cambodia has seen a threefold population increase over the last 60 years that the population is 16,076,370 in 2017 and is expected to be nearly 19 million in 2030 [1,2]. Recently, this country has been enjoying an economic growth mainly contributed by construction, agriculture, tourism, and garment [3]. Recognizably, construction has been considered as an important indicator in supporting Cambodia economy that the number of total national revenue yielded from this sector alone is over 92 million USD in 2017 with combined value of approved construction projects of 6.42 billion USD consisting of more than 3,052 new construction projects equaling to 10.74 million square meters within the year [4,5]. However, there have been growing concerns about how efficient and effective the construction in Cambodia is since repeatedly reported problems are the low productivity rate resulting in large inter-provincial gaps thus low wage to the practitioners, the incapability to meet the housing demands, the inability to provide affordable housing to the publics, and the lack of technological integration [4].

Scientifically proven, precast method has been identified as one of the methods to solve the above shortcomings. Nevertheless, the uptake of this method in Cambodia is still at an early stage. Thus, this paper presents the identification of the significant factors impacting the adoption of precast method in Cambodia construction industry.

2. Literature Reviews

To start with, precast method refers to a construction procedure that most activities happen inside the factory where components and panels are casted, cured and then transported to the construction site for assembly [7]. Basically, precast construction involves four main steps starting from design to production, transportation, and assembly [8,9,10]. The following sections outline the 5 benefits and 25 hindrances that precast practitioners will receive and face.

2.1. Potential Benefits

Five potential benefits are realized upon the use of precast method. Firstly, precast construction has a high potential in saving the time of the construction project [11,12,13,14,15,16,17,18]. For example, based on the case studies of Gunawan (2013), three different construction projects were compared, and it was found out that the number of the workdays for the precast building accounted for only 60 to 65 days instead of 154 days [19]. Secondly, prefabricated concrete components can ensure a high-quality control and assurance [11,13,16,17,18,20,21,22]. To illustrate, precast components are manufactured in the controlled-environment factory, tested and inspected before and after installation at the construction site [20,21]. Plus, this quality control starts since the design stage where the accuracy and precision of the design are accomplished at a millimeter scale [13,22]. Thirdly, precast can achieve the overall cost saving [17,20,23,24,25]. Take for example, prefabricated concrete construction requires a minimum labor usage, and together with the indirect benefits yielded from time saving, high-quality control, cost certainty, reduced risks, reduced running and maintenance costs, reduced preliminaries and site overheads, the cost can be saved during the operation and maintenance stage, contributing to the overall budget saving [18,20,24,25]. Fourthly, prefabricated method is famous for its ability to minimize the wastes generated from the construction activity [17,18,24,26,27,28]. Previous researches have shown that waste can only be minimized at source ranging from the design process, and timber formworks usage on site is minimized up to 87% while water and energy consumption are reduced up to 70% and 20% respectively, making up to 30% of the total waste reduction on site comparing to cast-in-situ building projects [24,26,27]. Lastly, this method is capable of coping with the shortage of labor since most activities of this method are conducted in the factory, so there is no need for excessive labor on site [11,17,24,29].

2.2. Possible Hindrances

However, hindrances are also placed upfront whenever this method is adopted, and different countries have faced different drawbacks when precast technology has been implemented. The following sections explain 25 hindrances obtained from the reviews.

2.2.1. Design Incapability

To begin with, the unfamiliarity of the precast design has posed a threat to the designers since they have been comfortable with the conventional method design and are not ready to catch up with this contemporary construction method which is different by nature. For instance, the precast design requires an attention of the designers to meet the high accuracy and precision from centimeters to millimeters. In addition, the technical design is also an issue for most designers, especially with designing the jointing between each component and the compatibility of it [14,22]. Furthermore, the inflexibility of precast design has hesitated the designers as well as the project team from choosing precast design due to the unfrozen development design and possible changes. Moreover, the designer’s freedom and creativity are deprived of when designing precast building because the components are rigid and have to be compatible with one another, making the design to be very limited to suit the production and assembly process [18,21,30].

2.2.2. Lack of Government Promotion and Incentives

Expectedly, the government has always been looked up to as a mentor and supporter in promoting precast construction to the publics [17,22,31]. For example, the companies in China have little motivation to shift to this method when there is a lack of tax relief from the government. Thus, there is an insufficiency of proactive incentive policies in making the contractors as well as practitioners to be enthusiastic in adopting precast method for their construction. In addition, without a leading promotion from the government, the uptake of precast technology by the practitioners still remains defensive with an example in China in 1980s when there were many quality problems in regards with precast construction method [22].

2.2.3. Lack of Local Policy Support and Regulation

The local policy support and regulation play an important role in driving precast technology to have a sound success since the municipality is viewed as an authority in forming the regulatory mechanisms and developing a policy to support this construction method [17,18,22,31,32]. In contrast, the absence of this legal system will cause developers, practitioners, and end-users to be reluctant in taking a lead to invest in precast technology.

2.2.4. Lack of Manufacturing Capability

Producing prefabricated components in the factory is a challenge due to the reason that most precast works are done in the design and production stage. Furthermore, finding the support from the local molding suppliers to meet the design demands is an obstacle to cope with, alike what has been happening in China as an example. Eventually, the precast builders do not have to only invest in the machines and the factory setup but also the molding, which means that a huge precast investment is needed for them to have a fully functional manufacturing capability [22]. As an example, Farzad Pour Rahimian (2017) founded that it is hard for the precast manufacturers in developing country to meet the mass demands for housing due to the lack of the production capability as what has happened in Nigeria [18]. As a result, the lack of manufacturing factories is normally seen at countries where precast construction is in its early stage.

2.2.5. Product Quality Problem

Ensuring that producing precast components meets a high-quality check is a challenge [12,22,33]. For example, deformations or defective connections usually appear in precast components which result in connection cracking or water leaking, and this will cause a long-term maintenance issue [22]. Furthermore, the absence of quality monitoring mechanism places a risk to the production line and the assembly team. For example, the prefabricated concrete component system in China is limited because there is no governmental authority or professional who can monitor the manufacturing procedures. Moreover, the bad image of precast buildings caused by the poor earthquake resistance, poor quality sealants, water seepage, and inadequate thermal or sound insulation measures dissatisfy the practitioners and the housing buyers from going for precast buildings [33].

2.2.6. Lack of Standardization System

Standardization system makes precast components compatible with one another. Evidently founded, there was an agreement that there is a lack of joint and beam standardization as indicated by 56% of the practitioners in Malaysia while 52% of them said that there was also a lack of column standardization [34]. With precast standardization system, the practitioners can select matched components by complying with the requirements of the relevant modules. Eventually, the composition of each component can be ensured to be according to the principle of standardized production. Hence, a variety of housing parts can be accurately installed at the specified site. However, with the absence of this system, each component may not be interchangeable and will cause the manufacturers and the builders not to be able to obtain the economies of scale from choosing precast method [22].

2.2.7. Lack of Skilled Labor

Precast technology is considered to be a modern technology for the construction industry. Thus, it requires skilled labor to operate both inside the factory and on site for the assembly. That is, the lack of skilled labor exists as a barrier for the industry in taking up precast method for construction. For example, there is a lack of skilled labor for the production line and the installation in China as the whole process of precast construction is very complicated. As per procedure, the components are produced in advance, and it needs to be matched and installed accurately along with the factory's instructions. In addition, it is difficult to remedy the mistakes when components are not fitted or when jointing are not compatible [22]. Furthermore, the labor skills are different between the traditional and precast method, so there needs to be a reform in the organizational structure in the training and employment of the local labor [12]. Thus, it requires highly skilled workers to ensure that the process is conducted accurately and timely.

2.2.8. Insufficient Training and Upskilling

Construction is generally known as a favored job for the migrant workers since little training is required, so low wage is expected. For example, a difficulty for the construction firms in China to spend the budget for essential training for their labors is present. Consequently, when it comes to precast technology, these workers could not meet the requirement that it needs. Thus, causative problems happened in the China in 2009 when one residential project in Shanghai had wall cracks, leakage, and seepage problems as an example. In contrast, the house owner criticized the technology severely while it was clear that the workmanship was the cause. In addition, the nature of practice between cast-in-situ and precast method is completely different, so the cast-in-situ workers need to go through training to operate the machines and to install precast components on site. Thus, the training and upskilling for labors are in needs when taking up precast technology [6,22].

2.2.9. Incompetency of Technology and Equipment

Because precast method deals mostly with technology and equipment, it requires the operator as well as the production team to be familiar and able to use it. Similarly, regarding the assembly team, the know-how knowledge of operating equipment is a must as it uses cranes and hoisting machines to lift the components from one place to another for installation. However, the construction industry is still conventional and depends heavily on manual force [22,33].

2.2.10. Lack of Supply Chain

Zhai (2013) claimed that the contemporary status of the construction industry can be described as a diversity of fragmented trades that are difficult to coordinate owing to the lack of supply chain. Thus, although there are many individual construction technologies, industrial supply chains, supporting technologies and large-scale production systems are not present. For example, the production parts in China need to be standardized, serialized, scaled, and universalized to gradually make the precast supply chain system last in the longer term. Additionally, a high-level integration among industrial construction partners is required since this is necessary in maintaining manpower, materials, and equipment for precast projects [22,33].

2.2.11. Monopoly Dominance

Monopoly dominance happens when there are only a few manufacturers producing precast. For example, this happened in Malaysia when it was hard to adopt precast method for the construction due to the few manufacturing facilities, leaving them no choice but to choose one. In addition, not only the manufacturer is monopolized but also the contractor to build the precast building. This is due to the lack of the know-how knowledge that has placed many contractors to have little chance in winning the projects since the developers choose only the same construction firms to do the precast work. Eventually, when monopoly exists, production and installation price will be raised [34].

2.2.12. Poor Coordination and Collaboration

Precast construction is different from that of the cast-in-situ method because it involves additional activities such as manufacturing, transportation, erection, and assembly of prefabricated components. Thus, it needs the participation from a large number of practitioners and interfaces. However, the subcontractors and the suppliers in the manufacturing and delivery chain have a poor creditability that extensive efforts are needed to guarantee cooperation among the practitioners, which is undeniably time-consuming and often inefficient. For example, delays in production or construction, changing orders and over budgets may be encountered due to ineffective decisions in adopting precast method. Hence, this method will not be able to perform its intended purpose to result in the benefits. Additionally, improper decision and consideration on the precast method matter will absolutely alter the performance, result and quality of the projects. Therefore, time delay is a typical consequence of this type of risk. Thus, communication, teamwork, problem solving, and analytical skills are necessary for the wider adoption of off-site production [33,35].

2.2.13. High Initial Cost

Precast technology has been notorious for its high initial cost [6,16,17,18,22,34]. Compared with the conventional construction method, the starting cost of precast method includes the cost of building the manufacturing factory and purchasing casting beds, machines, and equipment [16,22]. In addition, other problems that raise up the initial cost for precast technology investment includes the high transportation cost, high capital cost or front loading, upfront investment on the research and development, and the lack of proper utilization [34]. Comparably, prefabricated construction method will incur the cost 20% higher than the conventional method. In addition, the mechanized construction will increase the spending around 7% higher in regards to the traditional construction [17].

2.2.14. Lack of Economies of Scales

Precast construction method will yield its intended benefits only when the production units meet the concepts of the economies of scales. However, it will be the opposite if there is no mass production of the components, or if the shape of every component is different, which requires many different casting beds and moldings [22].

2.2.15. Economic Risks

Since there is a need for a huge investment in precast technology, it is a major challenge for the developers when economic risk is considered. For example, the initial investment may not be returned because the market changes. Plus, it can be due to the high upfront investment needed to establish a factory and availed of fabricated molds to produce fabricated components, becoming the cost of fixed assets comprising a portion of the product price [33].

2.2.16. Lack of Uniform Standards, Guidelines, and Codes

The absence of uniform standards, guidelines, and codes poses a threat to the practitioners when adopting precast method for their projects [17,22,33,35]. For example, the absence of universal technical standards is identified to be one of the hindrances to the development of precast method in China since there are no industry peremptory norms for precast construction, except for those practitioners who have participated in setting up their own standards [22]. In addition, inappropriate design codes and standards for industrialized building influence the quality and safety performance of a product. For example, in Industrialized Building System (IBS) implementation in Malaysia, construction components are produced and manufactured in a standardized line. Hence, the codes and standards of the line directly affect the component quality. Thus, the risks of an inappropriate design code can lead to a number of consequences such as unmatched parts and leakage in the adjoined parts of the prefabricated components and the main structure [33].

2.2.17. Resistance from Customers and Professionals

The resistance from customers and professionals also causes a difficulty in adopting this method, and it is due to the inadequate understanding of precast method benefits [9,17,18,22,31,33,34,35,36,37]. For instance, a majority of the construction companies do not fully realize the positive features that prefabricated concrete construction brings with [17,36]. In addition, the lack of assessment tools in assisting the practitioners to make a better decision when taking up precast can also make them not to try precast technology. As an instance, most decisions made in the precast method were based on the rules of thumb and the experience of the design team [31,35,37]. Furthermore, the lack of awareness and acceptance from the engineers in the field also puts a barricade in the decision-making process. Previously founded, though several participants were aware of precast method, only a few of them understood the basic principles, procedure, management task, and technical task in implementing this technique. Moreover, most construction firms are not mentally, technically, and financially ready to take up this technology for the projects and tend to reject it due to its high initial cost requirement [18,34]. What is more, uncertainty also plays a role in making the practitioners to be reluctant to go for this technology. For example, even though China government has been proactively promoting the adoption of prefabrication to the construction practitioner, it has been reported that only 10% of completed domestic housing project included prefabrication in constructions over the past 10 years while in Malaysia, the level of IBS usage is still low even though its implementation has started since early 1960's [22,31,33,34].

2.2.18. Lack of Expertise

The lack of expertise will lead to another barrier in implementing precast technology in construction. Poor design, poor plant management and production, and poor erection practices may lead to severe conflicts among the project stakeholders in the initial stage, failures during the production stage, and delays in delivering components to the site and in the erection schedule. In addition, errors and defects in design, improper assembling and hoisting of precast components on site, and incompetent operation of technology and equipment are associated with the lack of expertise [17,33].

2.2.19. Lack of Management

The lack of management is considered to be a risk in taking up precast technology [6,33]. For example, project clients, builders, subcontractors, and suppliers in the China industry have limited experience in precast project. Eventually, there have always been disputes such as where to place the prefabricated components and some other disagreements which are resulted from the unfamiliar management of precast technology [33]. Furthermore, the on-site management is also an important criterion in managing precast work. Generally, construction quality is largely dependent on acquired experience while precast stakeholders are working on a trial-and-error basis. Consequently, this has caused the construction to have a poor quality, safety-related accidents, time delays, cost overruns, and other risks. In addition, the insufficient stacking management and ineffective decision in selecting suitable locations for stocking the components and tracing them for dispatch happen, resulting in the components to be often exposed on the yard. Moreover, safety issues are always common as the elements are bulky and heavy which is potentially hard the assembly team. Adding to that, the resistance nature to change by precast components will increase the risk of adopting this technology when there is an ineffective precast management on site [6,33].

2.2.20. Long Lead-in Time

As per precast requirement, the precast design needs to be ready before the production starts so that there will be no mistakes during the erection time since remedying the components on site is difficult and almost impossible. However, this characteristic has hesitated the clients, designers, and the contractors from using it because the use of off-site construction could delay the beginning of the project on site [12,33].

2.2.21. Lack of Monotone Consideration

The monotone type of precast structures cannot offer a diverse choice to the consumers, thereby limiting the demands for prefabricated concrete elements from certain customers. For example, the monotone precast shapes in the projects cannot satisfy the diversity and personality requirements of consumers because of the low level of prefabrication techniques in China [33].

2.2.22. Lack of Standard Components Manufacturers

In optimizing the full utilization of precast construction, there is a need for standard component manufacturer. However, this has not been met. For instance, it is difficult in providing a large-scale production of standard component to the Industrialized Housing projects in China since there are very few off-site construction standard component manufacturers, and it is also hard for the contractors on site to guarantee the quality, mechanization, and standardization [16].

2.2.23. Lack of Research and Development, Support Services, and Technology Center

Local research and development, support services and technology center and testing laboratories help to strengthen the implementation of precast technology into the industry. In contrast, the lack of ones will weaken and hinder the practitioners from using it. For example, this is the case in China where the contractors are reluctant to use precast components for their projects when there is no laboratory to prove the quality of the structure. In addition, most manufacturers of precast components cannot provide a systematic, customized, mechanized and standardized production process needed for precast housing in general. Moreover, the insufficient industry investment in research and development will be a constraint during the decision making by the stakeholders as there is no much local information about precast technology [16,31].

2.2.24. Lack of On-site Cast Yard, Access, and Limited Space

Generally, the construction site in the urban area often has problems with the available space for placing materials. Eventually, this prevents the stakeholders from choosing precast method since there is a need for space to stock the components before erection starts. To illustrate, the construction team in Hong Kong could not afford to find any available space nearby the site for placing the components, causing them to set up their prefabrication yards far away from the site thus amounting for higher cost of the transportation. In addition, potential difficulties in gaining access to the construction are often resulted from the thick and bulky components, which eventually makes it hard to lift [12].

2.2.25. Transportation Issues

For the vertical transportation, the lack of hoist equipment capacity prevents the construction team from using this technology for their projects. Based on the consistent previous findings, the use of precast units may extend the concreting floor to floor cycle from the normal 4 to 5 or 6 days due to the reason that much time is spent on delivering the components vertically from the ground to the designated floors as this will depend on the weight and the size of the panels as well as the lifting capacity of the machines. Eventually, this will incur the costs and increase the time of the project. For the horizontal transportation of the precast panels, most manufacturers have chosen to set their factory in the remote area as to absorb the cheap labor cost and the land price. However, this benefit will be degraded by the incurred cost of transporting the elements from the factory to the construction site, and since the components are large and heavy, only a few pieces can be stacked on the truck and transported at a time. In addition, due to the strict traffic regulation in some countries, precast delivering truck can only be on the road during the off-peak hour which causes more time to be spent on the horizontal transportation [12].

3. Methodologies

Derived from the descriptive cross-sectional research, this paper aims to identify the significant factors impacting the adoption of precast method in Cambodia construction industry. Following sections are the methodological steps.

3.1. Research Scope

To begin with, the research is scoped down by five important criteria. Those criteria are the research emphasis on Cambodia building projects, the unit of analysis of engineers with either past or current precast working experience, the study coverage of the design, production, transportation, and assembly process, the prospect of the construction industry, and the prefabricated building components only.

3.2. Conceptual Framework

The conceptual framework is arranged in a crossing coordinate. In addition, each factor is subtracted into several questionable items based on the literature reviews. On the one hand, the vertical axis consists of Design, Production, Transportation, and Assembly Group [6]. On the other hand, the horizontal axis consists Push, Pull, Enabling, Barriers, and Industry Nature factors. In addition, based on the literature reviews in Section 2, those 25 main factors are subdivided into 462 questionnaire items.

By definition, Push factors pressurize or force the practitioners to adopt precast method by any party whereas Pull factors are the encouraging or convincing factors for the practitioners to intrinsically choose this method. In addition, Enabling factors are the facilitating platforms or supports for the practitioners to successfully and effectively adopt precast method for construction. That is, without the presence of these factors, the performance of precast method is not affected but with the presence of this, the method is highly enhanced. However, Barriers refer those challenges or disadvantages attached with precast method, and Nature Industry factors are the common perceptions of precast practitioners and users that are resulted from the lack of understandings towards precast method [39,40]. Figure 1 combines the axis together where Push, Pull, Enable, Barrier, and Industry Nature are dotted with 1, 2, 3, 4, and 5 in order while Design, Production, Transportation, and Assembly are abbreviated with D, P, T, and A respectively.

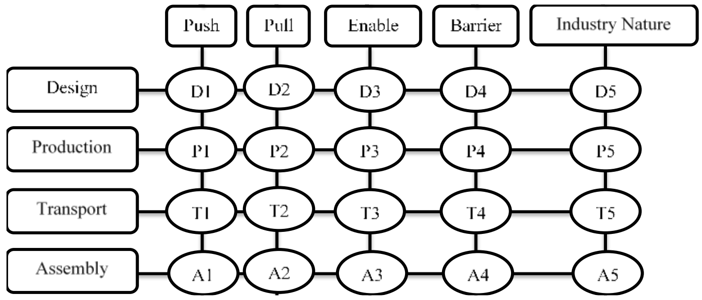

Figure 1 Conceptual Framework

3.3. Data Collection

Regarding the data collection, this research study adopted the closed-ended questionnaire consisting of 6 sections such as the brief research information, the respondent basic information, the design issues, the production issues, the transportation issues, and the assembly issues, and it was conducted via face to face using Likert scale ranging from 1 to 5 [38,41,42]. The items in the questionnaire were subdivided from the benefit and hindrances factors obtained from the literature reviews.

Procedurally, it was tested against validity and reliability test before the mass distribution started. For the validity test, 3 practitioners with at least 2 years of precast working experience in each vertical-axis group were invited to validate the questionnaire using Index of Item-Objective Congruence score (IOC) in which the items that got the score of less than 0.5 were eliminated. As a result, out of 462 questions, only 276 questions passed the test as listed in Table 1. Then, the reliability test was carried out with 30 respondents answering the revised questionnaire. Finally, the results were analyzed to find out the Cronbach's Alpha value as shown in Table 2. Statistically, Cronbach's Alpha is a measure of internal consistency. That is, it tells how closely related a set of items are as a group. It is usually considered as a measure of scale reliability. In other words, how reliable the answers of the measured items are. Based on most social scientific researches, a Cronbach's Alpha value of more than 0.7 is considered as acceptable [38,41,43,44].

Table 1 Number of Questions in Each Group

Number of Questions	Design Group	Production Group	Transportation Group	Assembly Group	Sub-Total
Push	11 questions	6 questions	1 question	16 questions	**34 questions**
Pull	11 questions	12 questions	1 question	12 questions	**36 questions**
Enabling	13 questions	6 questions	6 questions	25 questions	**50 questions**
Barriers	24 questions	62 questions	17 questions	35 questions	**138 questions**
Industry Nature	10 questions	3 questions	1 question	4 questions	**18 questions**
Sub-Total	**69 questions**	**89 questions**	**26 questions**	**92 questions**	**276 questions**

Table 2 Cronbach's Alpha Value

Group	Design	Production	Transportation	Assembly	Overall
Cronbach's Alpha Value	0.987	0.984	0.917	0.975	0.965

3.4. Sampling Methods and Respondents Identification

To start with, the study adopted purposive sampling method due to the difficulty of the researcher to spot the total number of engineers who have worked or are working with precast building projects in Cambodia since precast industry is still in its early stage, thus no sampling frame. Then, the snowball method is adopted by asking each respondent for their working connections with other engineers who are in the precast industry so as to increase the sample number proportionally [38,41,44]. Figure 2 summarizes the sampling method for this research study.

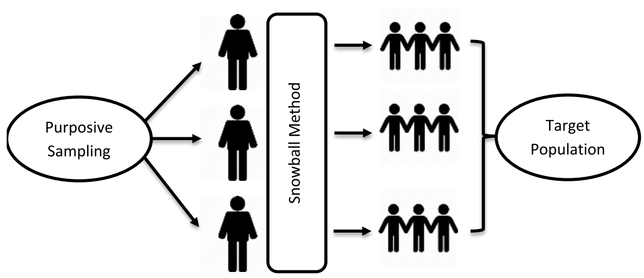

Figure 2 Sampling Methods

Based on the conceptual framework in the previous section, the key informants are selectively the precast engineers with a different range of working experiences from 4 different groups such as designers, manufacturers, deliverers, and assemblers a depicted in Figure 3.

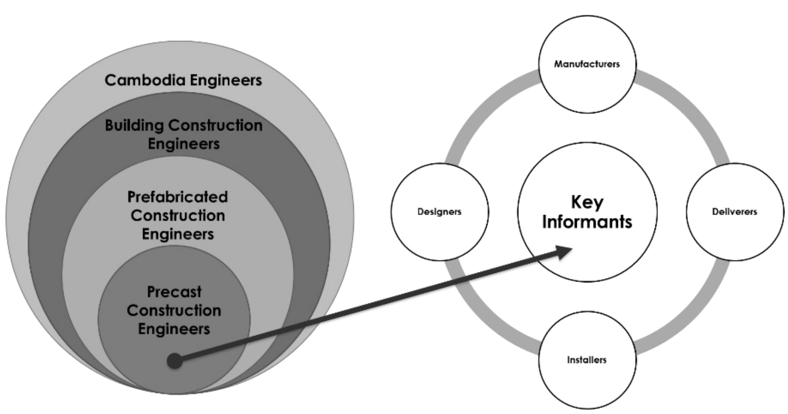

Figure 3 Key Respondent Identification

4. Result

At the end of the data collection, 44 respondents have volunteered in answering the questionnaire as listed in Table 3. Analyzed using descriptive statistics, Mean, Standard Deviation, and Coefficient Variation are listed in Table 4 which shows only the top factor of horizontal-axis group in each vertical-axis group.

Table 3 Number of Each Group's Participants

Group	Designers	Manufacturers	Deliverers	Assemblers	Total
Number	16	5	6	17	44

5. Discussion

First of all, top 5 significant factors in Design group are discussed. To begin with, providing a clean construction site was rated as the most important reason that pushed the designers to choose precast method which is due to the benefit of precast to minimize the waste. This factor was consistently found in China as the first ranked factor in terms of sustainable construction approach, and as having been repeatedly reported, Cambodia construction industry is not embedded with the environmental sustainability in its practice [16, 47]. In addition, similarly founded to be the essential characteristics of precast adoption in Malaysia and Thailand, the guaranteed quality control and assurance by the manufacturing factory was agreed by the respondents as the top pulling factor, which is owing to the benefit of precast to provide a quality product. Plus, this was also supported by one study in Cambodia where the quality problem was due to the poor schedule performance management that led the works to be finished in a hurry, thus neglecting the quality [15,45,47]. Next is the provision of testing and verification laboratory as a top supporting factor that enables the precast design to be successful, which is grouped under the lack of research and development, support service, and technology center as a barrier if it is absent [7,39]. However, the top preventing factor of the Design group was the lack of confidence by the designers when they are required to design precast which is due to the design incapability in Cambodia. As founded in the study of evaluating the impacts of the design errors in Cambodia, it was found out that the structural design error was a serious issue in Cambodia as it could lead to reworks, cost overruns, schedule delays, and unsafe environments which eventually affected the project performance, and it was also partly because of the limited technology available in Cambodia [48]. Last but not least, the resistance from the customers regarding precast building type was acknowledged to be the top industry nature factor [22,34]. This was also supported by one study in Cambodia that the customer factor was ranked forth as a significant influence in the design functions [49].

Table 4 Top Significant Factor

Vertical Axis	Horizontal Axis	ID	Factors	Significance Mean	Standard Deviation	Coefficient Variation
DESIGN	*Push*	D1	Provide a clean construction site	3.69	1.30	35.32%
	Pull	D2	The guaranteed quality control and assurance by the factory	3.88	1.02	26.44%
	Enable	D3	Testing and verification laboratory	3.63	1.15	31.65%
	Barrier	D4	Designers lack of confidence on precast products	3.69	1.35	36.68%
	Industry Nature	D5	The resistance from the customers regarding precast building type	3.63	1.15	31.65%
PRODUCTION	*Push*	P1	Reduce the total construction time	4.80	0.45	9.32%
	Pull	P2	Reduce energy consumption	4.60	0.55	11.91%
	Enable	P3	Presence of precast product quality monitoring and assessment system	4.60	0.89	19.44%
	Barrier	P4	Lack of government's initiatives in promoting precast products	4.80	0.45	9.32%
	Industry Nature	P5	The precast end-user criticizes on the precast technology instead of the production	4.40	0.89	20.33%
TRANSPORTATION	*Push*	T1	Sufficient market demand	3.00	1.89	63.25%
	Pull	T2	Precast monotone components	4.00	1.09	27.39%
	Enabling	T3	Sufficient equipment to do the vertical handling	4.67	0.52	11.07%
	Barrier	T4	Higher transportation cost	5.00	0.00	0.00%
	Industry Nature	T5	The publics do not feel safe when seeing the truck delivering the bulky components	4.00	1.54	38.73%
ASSEMBLY	*Push*	A1	Requirement by the client/consultant	4.18	0.53	12.66%
	Pull	A2	Construction duration reduction	4.41	0.62	14.02%
	Enabling	A3	Acceptance from construction parties	4.24	0.66	15.68%
	Barrier	A4	Lack of precast installation expertise	3.71	0.85	22.91%
	Industry Nature	A5	Changing orders by clients always happen	3.76	1.25	33.24%

Second of all, another top 5 factors are discussed in the Production group. To start with, the reduction of the construction time was agreed by the respondents to be the most important factor which pushes them to use precast method. Evidently proven, precast method could reduce the construction time up to 20.49 percent in China and 30 percent in Malaysia [11,24]. Arguably, Cambodia construction industry is at the brisk of falling behind the schedule due to several factors, but all of which, the unrealistic project scheduling was ranked second as the most important factor [50]. Furthermore, the reduction of energy consumption was rated as the most significant pulling factor by the production group, and a consistent finding was in the study in Hong Kong where precast method was promoted in order to reduce the energy consumption [24]. That is, this has solved the problems founded in the study that Cambodia construction is not embedded with sustainable practice [47]. Moreover, the presence of precast product quality monitoring and assessment system is affirmed to be the most important support for the production chain. Previously finding also concluded that the absence of this system is ranked as the fifth risk in China precast production line [33]. Nevertheless, the Production group also faced with the lack of government's initiatives in promoting precast products to the publics as the top barrier for the production expansion. Similarly founded, this factor ranked third as the stimulator in boosting the uptake of precast in Hong Kong if it is provided [21]. Last but not least, the criticism by the precast end-users on precast technology has placed a burden for the Production group as a top industry nature. Supportively, this factor was investigated to be the third challenging factor to the promotion of industrialized residential housing in China due to the reason that the homeowners criticized precast technology instead of the poor workmanship [22].

Third of all, for the Transportation group, top 5 factors are illustrated. Firstly, the sufficient market demand was rated as the top pushing factor to invest in precast delivery as similarly founded to be one of the top economic risks in industrialized building market China [33]. Secondly, the monotone shape of the precast components was agreed to the top pulling factor for adopting precast, and supportively, Cambodia house owners are found to be highly involved in the design preference [21,49]. Thirdly, sufficient equipment to do the vertical handling was rated as the top enabling factor which eased the delivery process of precast components, and it was also previously researched to be one of the barriers in adopting precast in China when it is absent [9]. Fourthly, this group claimed that high transportation cost was the main barrier for the delivery work. Similarly founded in Hong Kong, due to the high investment cost of establishing the factory inside the urban area, most factories are built far away from the construction site, which eventually incurred the cost of transportation [7]. Fifthly, the public perception of not feeling safe when bulky and heavy components are stacked on the truck was rated as the top factor in the industry nature, and it was also agreed to be a barrier to precast adoption in China [22].

Last of all, in terms of the Assembly group, the last top 5 factors are explained. Initially, the requirement by the client and consultant to the contractors to use precast method for the project was rated as the most important pushing factor, and it was found consistently in the study in China [21]. In addition, they agreed that the construction duration reduction was the top pulling factor to use precast method, similarly found in the study in Hong Kong [46]. Furthermore, the acceptance from the construction parties enables precast adoption as the top enabling factor with a consistent finding in the study in Malaysia. Plus, Cambodia construction industry is heavily influenced by the perspectives and preferences of the construction stakeholders involved in terms of design choice [34,49]. On the contrary, the lack of precast installation expertise blocked the group from implementing precast method effectively for the project, and it was similarly founded in the study in Hong Kong as one of precast limitations and another study in Cambodia as facing the technical management on site [46,50]. On the other hands, frequent changing orders by the clients also are a difficulty to choose precast method for the project as the top industry nature factor since precast was found to be resistant to changes, and one study in Cambodia is also found to be supportive of this claim as frequent changes occur during the construction stage which eventually leads to the conflict of cost incurred [29,49].

However, it is important to note that each factor has a different coefficient variation even though it is ranked based on its significance Mean value. According to the data in Table 4, it can be concluded that (T4) High Transportation Cost is the most reliable factor as there is no deviation in terms of the respondent's answers while (T1) Sufficient Market Demand is the least reliable factor because the coefficient variation value of this factor is the highest among all. In other words, every sample agreed that high transportation cost is the most important barrier that causes the level of precast adoption in Cambodia to be low as this incurs the project budget while the sufficient precast demand is disagreed by a majority of the samples as not having much impact on the level of precast adoption in Cambodia.

6. Conclusion and Suggestion

Precast construction has been well-known for its benefits and notorious for its drawbacks. Thus, Cambodia construction industry needs to learn from other countries regarding the adoption approach and implementation strategy and take into considerations the factors which were found in this study. For the suggestion of further studies, the prospective researchers should take into account of civil precast infrastructure since the application of precast method on the public infrastructure can also be correlated with the implementation of this method to the building industry.

Acknowledgement

The authors would like to express sincere thanks to the Graduate School and the Faculty of Engineering at Khon Kaen University for providing research funds, and construction practitioners in Cambodia who have participated in the research data collection.

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