A REVIEW ON THE COMPARATIVE STUDY BETWEEN THE PRECAST AND CONVENTIONAL BUILDING CONSTRUCTION

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Abstract
The precast building construction method emerged in Malaysia construction industry as an approach to accelerate the productivity. This paper aims to provide an overview on the critical elements used for the comparative studies in precast and conventional building construction methods. Previous research works are reviewed to identify the standardization in comparison between the chosen building systems and the critical elements contributing to the economic benefits. It is important to evaluate for the standard comparison between both construction methods in the assessment for better choice among the two-construction methods.

Keywords: *Precast construction method; Malaysia construction industry; productivity; conventional construction method; critical elements; comparative studies*

INTRODUCTION

The conventional construction method is the oldest method which has been practiced in the construction industries worldwide. Concept of conventional construction method is commonly referred to as structural components that are fabricated on construction site, on- site installation of steel reinforcements, and the use of timber or plywood formworks for the casting of components (Andres and Smith, 1998; Badir and Kadir, 1998; Haron et al., 2005; Lou, 2012; Aishah and Ali, 2012; Lou and Kamar, 2012; Rahim and Syazwan, 2013).

Andres and Smith (1998) defined conventional construction method as more expensive since it consumes more raw materials such as the timber formworks and steel reinforcements during the on-site fabrication of building components. It also uses more labours for the cast in-situ works. However, conventional buildings are mostly built from conventional construction method. Due to high labours consumption for site works and low speed construction, conventional construction method is more costly (Badir and Kadir, 1998).

On the other hand, precast construction method is specific to structural components which are standardized and prefabricated or produced off-site (factories or plants that are located away from the construction site). The components are then transported and assembled onsite (Rohana and Siti, 2013). Malaysia construction industry defines precast construction method as industrialised building system (IBS) as it involves mass production of components through industrial methods (Azhari et al., 2012). Precast construction method has been defined by various researchers as an alternative construction method towards the adoption of prefabricated and mass production of the building works which tends to improve the productivity, quality, time and cost saving (Junid, 1986; Khaiat and Qaddumi, 1989; Badir and Kadir, 1998; Sarja, 1998; Gibb, 1999; Trikha, 1999; Warswaki, 1999; Parid, 2003; Trika, 2004; Haron et al., 2005; Ekholm et al., 2005; Marsono et al., 2006; Omar and Rahman, 2006; Chung and Kadir, 2007; Abdullah et al., 2009; Ahmad et al., 2011; Abedi et al., 2011; Construction Industry Development Board, 2017).

Khaiat and Qaddumi (1989) stated that precast construction method reduced the amount of site labour involved in building operations since the elements are standardized and prefabricated in factory. Badir and Kadir (1998) described precast construction method can comprise all various site works such as temporary facilities, building frames, building finishes and equipment. It is based on the industrialization concept to produce the prefabricated components in factory and it integrates all the process of preassembly, organization and completion of project with well management (Gibb, 1999; Parid, 2003; Ekholm et al., 2005; Omar and Rahman, 2006; Marsano et al., 2006; Chung and Kadir, 2007; Ahmad et al., 2011).

In correspondence to those studies, Trika (2004) defined the precast construction method as the building system of which all the building components are erected and assembled through mechanized means and involved minimal site works. It is a set of interrelated activities between the managerial and technological for the production and installation of these elements (Junid, 1986; Sarja, 1998; Abdullah et al., 2009; Abedi et al., 2011).

As a summary, all the definitions from the researchers can be generalised into the significance of precast construction method to view as technological, process integrated, standardised, well-planned; organised; and high-prefabricated production.

To date, conventional construction method still cannot get rid of the problems of long construction time, low productivity, poor safety records, and large quantities of waste (Egan, 1998; Eastman, 2008; Azam et al., 2013). Instead, Malaysia construction industry worked a great attempt in the adoption of precast construction method. Precast construction method has restructured the entire conventional construction process in order to improve and speed up both the design phase and production planning. The precast construction method has emerged as a new fast track construction method to boost the growing economy. It raises the significant advantages in terms of shortened construction time, lower overall project cost as well as better quality. Besides, it also enhances occupational health and safety, more means for sustainability with less construction waste, less environmental emissions, and reduction of energy and water consumption (Ismail and Shaari, 2003; Lai, 2005; Dabhade et al., 2009; IEM, 2001; Chen et al., 2010; Yang and Yunus, 2011; Azam and Zanarita, 2012; Bari et al., 2011; Ismail et al., 2012; Shamsuddin et al., 2013; Jabar et al., 2013; Dineshkumar and Kathivel, 2015; Virendravyas, 2015; Construction Industry Development Board, 2017).

Ismail and Shaari (2003) interpreted precast construction method as not aimed to substitute the conventional construction method but an approach to decrease the reliance on labour, improve productivity with shorter construction time and maintain the quality. Lai (2005) indicated precast construction method as an attempt to show greater productivity, shorter construction period, improved quality and reduction in overall construction cost in large-scale precast buildings in Malaysia. Yang and Yunus (2011) and Shamsuddin et al. (2013) viewed that precast construction method is able to increase the profit in long-term for the stakeholders as the cost of the labour and materials can be reduced. In contrast, Azam and Zanarita (2012) stated that precast construction method does not have much difference in term of material saving as compared to conventional construction method but it has benefits in terms of quality and labour saving.

Precast construction method that is recognised as a fast-track construction method can offer time saving during construction which compensates the overall construction cost (Dineshkumar

and Kathivel, 2015; Virendravyas, 2015). Kathivel (2015) explained that the rapid construction rate by adopting precast construction method because the method reduces unnecessary handling and equipment time. On the other hand, conventional construction method consumes a lot of time during the on-site hardening of concrete with the usual practice of at least of 7 days to achieve its concrete strength. In correspondence, Virendravyas (2015) conducted a comparative study between precast and conventional construction method and stated that precast construction method registered almost the whole saving on plastering and finishing works. Similarly, according to the previous data reported from Construction Industry Development Board (CIDB) (2017), it shows that the precast construction method gives rise to cut down the construction costs as much as 15% in some instances. So, the precast construction method that produced in mass production can build a large number of buildings in short time at low cost. This stimulates the development of domestic construction industry at the meantime.

The implementation of precast construction method in Malaysia has a very wide range, from the iconic buildings to the infrastructures; such as KLCC, Petronas Twin Towers, National Stadium Bukit Jalil, Kuala Lumpur's Sentral station, KL's new international airport, Putrajaya Bridge, Light Rail Transit, and also the Monarail (Idrus and Utomo, 2008; Phang, 2017). The precast industry receives great encouragement by the government with the increase in incentives to motivate the saleable area, quality and sustainability. Despite the adoption of precast construction method on those high-profile projects and current existing conventional construction method is deemed to be '3D' (dirty, difficult and dangerous), besetting the perennial problems such as time delay, cost overrun and waste generation; the growth of the precast construction method is still slow. Therefore, it is essential to look at how the precast construction method is able to save cost and time for all the construction industry practitioners.

As in the year 2016, the total construction contracts in Malaysia are RM 124.96 billion. The public sector accounted for 23% and the private sector undertook the remaining 77 % of the contract values. The public sector took a total of RM29.07 billion involving the residential projects (RM 0.60 billion, 2 %); non-residential projects (RM 6.12 billion, 21 %); and infrastructure projects (RM 22.35 billion, 77 %). Comparatively, the private sector undertook the larger contract amounts with the total of RM 95.89 billion consisting residential projects (RM 28.62 billion, 30 %); non-residential projects (RM32.07 billion, 33 %); and infrastructure projects (RM 35.20 billion, 37 %) (Elias et al., 2017). From this statistic, it can be seen that the private sector is the major player in the construction industry but the adaptation of precast construction method in the private sector is extremely low at 14 %, as compared to 69 %in the public sector (Department of Statistic Malaysia, 2016). Thus, this clearly reveals that the private sector must take the lead to practice precast construction method in Malaysia.

Therefore, this paper intends to review previous research works carried out on the comparative study of conventional and precast construction methods with the focus on building projects. The types of structural components used for the comparative studies are addressed and critical elements involved in the comparative studies are also reviewed herein.

COMPONENTS OF PRECAST AND CONVENTIONAL CONSTRUCTION METHODS

Generally, the conventional construction method is divided into two major components. The first component is the structural system which is the cast-in-situ (cast in the construction

site) of the structural frame such as column, beam, and slab. The second component involves the construction operations which are the erection of timber formwork and scaffolding, installation of steel bar, pouring of fresh concrete and disassembly of formwork and scaffolding (Asiah et al., 2012).

The precast construction method is the most popular IBS system practiced in Malaysia construction industry (Alinaitwe et al., 2006). Figure 1 shows the IBS manufacturers in Malaysia (not including Selangor) in the year 2014. According to the statistics obtained from IBS Centre (2014), the data shows the increase in precast manufacturers from 15 in the year 2009 to 53 in the year 2014.

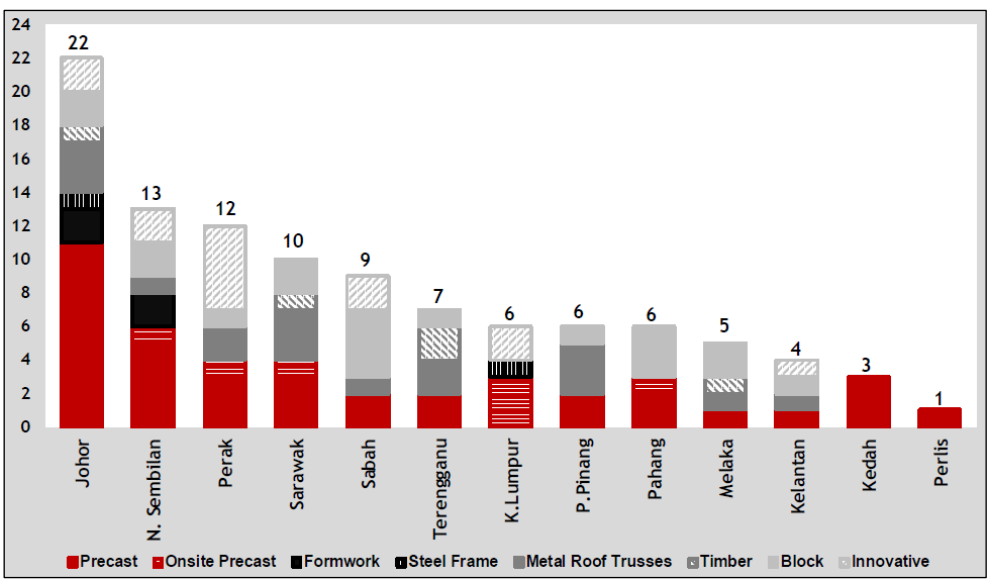

Figure 1. IBS Manufacturers in Malaysia (Not Including Selangor) in The Year 2014 (IBS Centre, 2014)

According to the Construction Industry Development Board (CIDB) (2013), there exists total numbers of 172 types of components listed as precast components. The precast components are further divided into precast building system and precast infrastructure system. The precast components must possess the six characteristics as following:

i. Production of prefabricated components through industrial process;
ii. Highly mechanized in-situ processes;
iii. Reduced labour during prefabrication of components and site works;
iv. Modern design and manufacturing methods such as utilisation of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM);
v. Systematic Quality Control to fulfil ISO 9000 principles;
vi. Create Open Building Concept for permitting hybrid applications, adaptable to standardisation and modular coordination (MC).

According to Construction Research Institute of Malaysia (CREAM) (2017), 'precast components' are defined as structural precast components and are divided into seven main categories, namely beam, column, half slab, hollow core slab, prestressed planks, staircase and wall (load-bearing and non-load-bearing wall). For example, the components that are

commonly installed in precast building system includes precast columns, precast wall panel, precast slab or half-slab, precast beam and precast staircase as shown in Figure 2. The principal of measure of precast construction method is through the use of standard prefabricate components from Malaysia Standard MS 1064 with repetition design.

Figure 2. Precast Building System (CIDB, 2013)

BARRIERS OF PRECAST CONSTRUCTION METHODS IN MALAYSIA

Although precast construction method is an ideal conceptualisation as compared to conventional construction method, it is still not able to cater the demand of the market. As summarised from CREAM in 2007, the barriers of adoption of precast construction method in Malaysia included lack of knowledge among designers; lack of standardisation; slow adoption from the private sector; monopoly of certain manufacturers, lack of special machinery and equipment; and lack of skilled workers.

Previous research studies have been carried out particularly to support the arguments. Researchers including Angela et al. (2013); Asmah et al. (2012); and Martinez et al. (2008) gave an overview regarding the problems on the knowledge among designers. According to Angela et al. (2013), lack of standardisation in design is a concerned technical issue that limit the practice of precast construction method. The project indirect cost will tend to increase and therefore it is not economical as compared to conventional construction method. Asmah et al. (2012) had conducted a research on the target group of G5-G7 contractors registered under CIDB within Sarawak region. It was concluded that most of the contractors are still lack of exposure and show limited application on precast construction method. The main constraint to the integration of the method in the local construction industry can be identified through the payment and investment method on precast components especially the weak level of implementation due to lack of knowledge and design standardisation which is still based on

conventional practice. In addition, it is surely a gap and hard to decide on the precast construction method as it requires more coordination and planning during the design stage. It is necessary for the client and construction professionals to carry out two-way information to make earlier decisions and have better communication to avoid expensive changes and variations to the design once production has started (Martinez et al., 2008).

The adaptation of precast construction method in Malaysia experienced the problems with regards to the lack of precast manufacturers and supplier causing the price of precast components to increase when the demand increases faster than the supply and the existence of monopoly which is not beneficial. This is supported by Khalfan and McDermott (2009) which stated that Malaysia is lacking precast manufacturers and it became worse when the adoption from the construction industry practitioners is slow and demand for the precast components is low. In addition, the limitation for the adoption of precast construction method is due to the perception among the stakeholders that precast construction method is mechanised based and it involves high initial capital for investment. Precast manufacturers will charge for an initial payment or deposit from the contractors for the purchase and delivery of precast components. Subsequent delivery of precast components would also require immediate payments. This may create cash flow problems to contractors as the project owner are more used to practice payment methods based on conventional construction work (Kamar and Hamid, 2009).

The Construction Industry Master Plan (2007) identified the low level of implementation of precast construction method was due to shortage of skilled workers and the increase in cost of hiring skilled workers. In correspondence, Chan and Osei-Kyei (2015) mentioned that too much reliance on foreign workers with cheap labour rate is the root cause for current Malaysia construction industry to continue practicing the conventional construction method despite the precast construction method is able to shorten the construction time and lower down the construction cost when building components are mass produced.

The arguments for the construction industry to promote the precast construction method mainly embrace on the economic or monetary perspectives ranging from quality, construction time and cost savings. A numerous research studies which included Rozana et al. (2015), Azman (2013), Yang and Yunus (2011), Jaillon and Poon (2008), Ding (2008), Ali et al. (2006) and Goodier and Gibb (2007) have been done previously and showed the dispute regarding the cost performances of precast construction method as compared to conventional construction method.

Ali et al. (2006) collected the data from 100 residential projects through a questionnaire survey and summarised that there was negligible difference in structural cost between conventional and precast method. Therefore, it upholds the tendency where most of the construction industry practitioners tend to choose the conventional construction method over the precast construction method since there is no motivation in the cost factor.

Goodier and Gibb (2007) and Ding (2008) highlighted the shorter construction time in precast construction method, hence showing significant cost saving. These results were in agreement with the study carried out by Jaillon and Poon (2008) which proved that the reduction of 15% of total construction time in the construction resulted a cost saving of 16% as well as in labour requirement on-site due to the standardisation process in manufacturing the building components.

Yang and Yunus (2011) proved that the cost for labour and materials reduced significantly when adopting precast construction method but Azman (2013) stated that contractors are reluctant to involve in precast construction method due to high-cost consumptions on materials and skilled-labour. Correspondingly, the economic attribute of precast construction method may offer a remarkable profit margin from its overall cost saving rather than an individual cost perspective since it offers faster in return-on-investment (ROI) of a project (Rozana et al., 2015).

As evidence from the survey done by the CIDB regarding the advantages of precast construction method, as listed from the most beneficial to the least beneficial are (1) less wastage; (2) cleaner environment; (3) less site materials; (4) reduction of site labour; (5) controlled quality; (6) faster project completion; (7) neater and safer construction sites; and (8) lower total construction cost (Majid, 2011). Therefore, it should be noticed that the total construction cost still remains as the primary concern on the selection of construction methods.

Although it is generally on accepted fact that the use of repetitive precast components contributes to appreciable cost savings in a high-rise project, it is not clear if such cost advantages apply in a low-rise landed house environment. In the interest of investigating the technical feasibility of precast construction method for landed houses, there is a need for comparison of cost on precast construction method versus conventional construction method for low-rise housing.

According to the report from the Research Design and Standards Organisation (2014), there still exists the root problem on the variation in the cost of precast components, which differs according to the type and size of construction. For small scale project, the total cost will be higher due to no production of elements in bulk. Instead, it results in lower cost for bigger projects. This is supported by the study carried out by Dineshkumar and Kathivel (2015) in India where it was found that the cost of construction for a double-storey residential building using precast elements showed 13 % more expensive than the cost of conventional construction method. Akash and Venkateswarlu (2016) addressed the same limitation by noticing that the increase or decrease in costs as a result of one more or one less unit of output causing the cost increase is more marginal than substantial. But mass production of repetitive precast units will eventually lower down the cost to a level comparable to conventional construction.

According to Azman et al. (2011), precast construction method creates high buildability for high repetition building particularly for the high rise building but this benefit is limited for the low rise building since it has less repetition. Anecdotally, precast construction method offers fast in two cycled projects if the sequence of work is planned properly. Due to high initial investment for the precast technology, it usually consumes much maintenance cost and it requires a few projects to cover the initial cost of precast technology.

In Malaysia, precast construction method is usually integrated into high-rise governmental projects or projects with high repeatability in structures instead of a low-rise residential project (Jaafar et al., 2013). The private sector is reluctant to adopt precast construction method as it was found not economical for building projects of less than 100 units or 5-storeys (Amir et al., 2015).

Generally, the two factors to escalate the efficiency of practicing precast construction method includes:

i. Designing of the building layout with maximum repetition of precast unit.
ii. Designing construction details to maximise the number of standardised components.

The concrete issue for the precast construction method can be identified direct or indirectly. The direct issue is always related to the elements, system, production, handling, assembling, and connection and demounting. The indirect issue to consider precast construction method are the precast concrete materials, technology, structural analysis and equipment. Therefore, the selective use of precast components within conventional building system may have economic and managerial benefits even in the case of small and heterogeneous projects with less design repetition (Senthamilkumar et al., 2014). Bhavani (2014) explicitly explained the importance of the design and planning phase and in the division and specialisation of human workforce in order to complete the project on high speed.

Conclusively, the main barriers that should be overcome to persuade the continuous development of precast construction method is to ensure the considerable profit for the clients and stakeholders in long-term income and expenditure (Hao et al., 2007).

CRITICAL ELEMENTS FOR COMPARATIVE STUDY BETWEEN PRECAST AND CONVENTIONAL CONSTRUCTION METHODS

Cost is regarded as the main critical factor in determining the nature of business, not least in the construction industry. Construction cost is the factual data which consists of cost estimating till finished quantities of a building. It is the fundamental to predict and plan the total executing cost of a construction work. Therefore, it is the most rational criteria and vital for evaluating the choice on construction method (Norazmi, 2008).

In Malaysia, there still exists arguable comparison or simply describes as ‘apples’ are being compared to ‘oranges’ to give ambiguous information for the comparison study prior to selection between the conventional construction method and precast construction method. The way forward for the comparison of the construction methods is to compare “apple to apple” (Henk and Peter, 1999).

Normally, the building owners, contractors, and investors adopted the construction cost indices to allow for the comparison of the building construction cost across the countries, such as multi-nationally or major urban area domestically where the construction cost indices are used to estimate the cost by taking into consideration of the local currency (Davis, 2010). The way to compute the construction cost by adjusting the purchasing power parity as an approach to correlate it to a reasonably cost relativity between two distinct localities was also suggested by McCarthy (2011). Although building economists updated the construction cost indices regularly, it is, however, cost estimation of an equivalent building based on per square meter basis does not take into account the different construction methods and ignores broadly the location conditions such as labour force availability, weather and terrains. Significantly, it impacted on the cost overruns and limited the construction industry development with regards to the choice of construction methods (Stapel, 2002). Previous studies on the cost comparison between two localities by using the construction cost indices carried out by researchers such as Stapel (2002), Walsh and Sawhney (2004) and Davis (2010) have not relatively linked the choice of construction methods and location-specific conditions.

Therefore, the more accurate comparative methods have been widely discovered over the time in order to improve the accuracy and develop more reliable comparison method between the conventional and precast construction methods. Previous researchers (Bouwcentrum, 1995; Eurostat, 1996; Lim et al., 2017) including the government body (Jabatan Kerja Raya, 2017) have published the guidelines for the purpose of comparative study.

In the comparative study between precast construction method and conventional construction method, there exist five types of key comparative methods for the estimation on construction project total cost. These include the cubic content estimation; floor area; unit valuation; bill of quantities; and approximate quantities. Cubic content estimation is the most simplified method used to obtain the project total cost of which the volume of a building is obtained through the product of dimension of the building (height × length × width) and assume the construction cost per unit volume. The floor area estimation method is based on the assumption of the area on the particular slab by multiplying its width and length and cost is counted by per square metre. Unit valuation method estimates the quantity of certain equipment of occupants that is constantly occupying the building based on unit cost.

Bill of quantities is the regular method practiced by the construction industry of which refer to the estimation on project total cost by referring to the cost calculated by the quantity surveyor on each of the materials and components used for the building. Approximate quantities are the most accurate method for estimating project total cost. It estimates cost by listing out all the components of the building in detail based on the construction drawing and calculates based on its typical unit cost of the respective component (Jabatan Kerja Raya, 2017).

The precast construction method is a concept to develop a prototype module that can be replicated and customised to suit varying needs and situations. Study on precast construction projects can be divided into 3 categories which are the fully precast project, partially precast projects, and selected components precast projects. The fully precast project integrates highly standardised and repeated precast components throughout the building design and construction. Partially precast projects combine both the use of conventional structural components and precast components in a building project while selected components precast projects refer to the building project that involves only a particular type of selected precast components in the building projects which aims for creative and aesthetic requirements (Lim et al., 2017).

In addition, Bouwcentrum (1995) and Eurostat (1996) suggested 3 methods for comparing costs of building projects which include the comparison of standardised identical buildings; comparison of standardised identical buildings with local modifications; and comparison of standardised identical buildings with similar functionality. Comparison of standardised identical buildings is about the comparison on the identical buildings based on the same drawing and specifications but this comparison method does not take into consider on the local modifications, codes, standards, and specifications. Instead, comparison of standard buildings with local modifications is more accurate as the cost is correlated to its local modifications, codes and specification levels. The third method, comparison of functionally similar buildings comparison of standardised identical is an approach where it includes the types of building as well as its functionality and aesthetic value fulfil the client's expectations.

Construction cost has all the complex and complicated elements. Ambiguity in the interpretation of cost performance in construction projects has become a major concern for both

contractors and clients (Proverbs and Xiao, 2002). It is necessary to address the project- related determinants and its effect (Proverbs and Xiao, 2002 and Elhag et al., 2005). According to Elhag et al. (2005), a reliable cost-estimating technique is delivered when the cost-determinants is fully considered. The cost-determinants included all the direct and indirect costs. Previous research studies carried out by Bubshait and Al-Juwairah (2002), Chan and Park (2005), Elhag et al. (2005), Stoy and Schalcher, (2007), Memon et al. (2010), Aini et al. (2012), Rohana and Siti (2013) focused on factors that affect the overall cost in construction starting from project estimation to completion. These studies affirmed that construction cost is directly affected by the competence in managing cost, technologies, economic as well as government policies.

Bubshait and Al-Juwairah (2002) carried out a survey from the group of contractors, consultants and owners had concluded that improper planning and managing in direct cost such as material cost has led to the financial-control problem which resulted in high construction cost. Similarly, Memon et al. (2010) had gathered research data for general construction project despite the selection on construction methods through questionnaire and statistical tools. This study concluded that poorly managed project scheduling especially in large government construction projects has generally influenced the construction cost in construction project. From those studies, it should be realised that the proper project management must be practiced in order to control the flow of construction cost. Besides that, labour cost is another crucial element in determining the selection of building construction method since the highly skilled labours implement in the precast building construction method always caused higher rate than the labours in conventional building construction method. Manufacture of precast components require a number of skilled works but these numbers are still in shortage and therefore must be hired in higher wage rates. This argument was supported by the study carried out by Chan and Park (2005). The study has randomly picked the sample study of Singapore's building projects valued at more than US$5 million and identified the crucial component caused the construction industry to facing problem in construction cost is the high-technologies and high-skilled worker requirement which tends to increase the cost, which is out of the cost estimation.

In addition, Aini et al. (2012) carried out a study towards IBS in Malaysia. The study was conducted through questionnaire survey to extract the views on determining the cost-influencing factors of IBS projects in Malaysia from IBS contractors' and manufacturers' perspectives. This study concluded that construction cost is impacted by economic and market condition which may cause the risk in cost overruns. Apart from that, Rohana and Siti (2013) gathered data from the ten samples of interviewers and emphasised that it is important to address the inter-relationship of cost factors which include labour, material and production cost in order to sustain the implementation of precast construction method in Malaysia construction industry.

Extensive studies have been done to identify the factors that affect the overall cost of construction projects. The research outcome suggests that various elements, ranging from project estimation to completion, will significantly affect the project cost (Memon et al., 2010; Elhag et al., 2005; Chan and Park, 2005). It is important to address all the project-related determinants and its magnitude in order to control the project cash flow. A representative comparison must take into account all the relevant elements which can be further classified into time-dependent and quantity-dependent cost components and contributed towards the direct and indirect cost such as labour, material, investment, general expenses, transportation and overhead.

It is however, as supported by CIDB (2016) and Lim et al. (2017), the relationship between the time, labour, materials and costs are always interrelated and cannot be analysed separately. It should be evaluated in its overall context. According to CIDB (2016), the method of costing by material quantities with a fixed factor for labour cost usually practiced by the local construction industry. But it should be realised that this method can lead to incorrect estimation. For instance, the labour usage in precast construction method is usually half of the conventional construction method. However, precast construction method may compensate for a 10% increase in material cost, but there is saving in time. Also, if properly designed and executed, precast construction method can lead to a much better capacity of work. The overall cost impact of precast construction method has, therefore, to take all these factors into consideration. Resulted from the less consumption of time and labour cost, the trend is that precast construction method become increasingly competitive compared to conventional construction method. Concurrently, in the research study from Lim et al. (2017), it was identified that material cost is a significant part of the precast construction method but it should not be evaluated independently of other cost-related factors. For example, by using more expensive precast construction method, direct labour cost is reduced. This is a significant consideration in a market like Singapore where labour cost has been expensive and are expected to continue to rise. Time-saving is another important factor, and this translates directly into lower preliminaries and faster project turnover. Thus, it will be easier to cater for the benefit of each construction method, either conventional or precast by considering the critical elements through the three main stages: design, production and construction.

During the design stage, the nature of the construction project can be used to decide the more favourable construction method. The main consideration is the project characteristics. Project characteristic tends to figure out the flow of project management and coordination (Stoy and Schalcher, 2007; Aini et al., 2012; Azman et al., 2012; CIDB, 2017). Somehow, precast construction method with repetitive components must be created with high buildability and ensure the competence of the heavy precast components to be stiff and rigid for handing and installation.

Aini et al. (2012) have conducted a questionnaire survey to study the factors affecting precast construction costs in the Malaysian construction industry. The survey comprised a total number of 44 contractors and manufacturers to look into the critical factors which include the project characteristics, contract procedure and procurement method, consultant, and design parameters, contractor's attributes, economic and market conditions, external factors and government's requirements. The results analysed from the relative importance index (RII) showed that factors related to project characteristic (88.18%), contractor's attributes (82.73%), economic and market conditions (80.45%) are common factors that can influence the construction cost of precast construction project.

It should be noted that the project cost is also influenced by the project characteristics such as project size; project type involving speed of construction, either fast-track or urgency for completion; and also, the repeatability and standardisation with typical floor plans in a multi-story building project. Adequacy of project management may also lead to the good level of coordination and control on the project cost overrun (Stoy and Schalcher, 2007).

Azman et al. (2012) carried out a study of precast concrete in Malaysia by applying a qualitative approach through a series of interviews and observations on 15 decision makers

from precast manufacturers with 5-year experience in precast system works and reported that about 33% determined the design-and-build as one of the four main themes in practicing precast building construction method. The best practice tender award for the precast system with design-and-build is able to control the whole project flow, especially during the construction period, with less change in the design stage.

In Malaysia, precast construction method is not a solution for certain construction works. For example, the method cannot be practiced in the construction of structures with unique designs. This is due to lack of design standardisation code in precast project design. Most precast manufacturers have their own respective design system which differs from the other in terms of size, type and installation method. The lack of consistency in design will complicate the installation process. (CIDB, 2017). Therefore, the design of the building layout is prior for the selection of building construction method.

At the production line, the quality control system is another vital element used to supervise throughout the production and manufacturing process to ensure the precast products have achieved higher quality and better finishes. On the other hand, the benefit of improved quality is appreciable but difficult to measure. Better quality means lower subsequent defect rectification costs, but its direct cost benefit is not as easily quantifiable. Therefore, during the production process, it is another concern to take up the initial investment and machinery cost for the precast construction method (Rozana et al., 2013; Rohana, 2016) and to consider the waste generated from both construction methods (Badir et al., 1998; Begum et al., 2006; Dani et al., 2014; Phang, 2017).

Precast construction method has the possibility to reduce the construction project total cost, in the long run, to overcome its high investment of the machinery at the start if it is widely adopted locally. As stated in Rohana (2016) study on the framework in term of process considerations of precast building construction system through semi-structured interviews targeted at construction industry players involved in the precast system at multi-levels, the results have shown that 80.2% of the respondents agreed that initial investment cost is the most important aspects of involving and producing the precast structural components and it must have comprehensive information and knowledge with regards to the construction method prior to control the project total cost in long-run. In addition, Rozana et al. (2013) carried out a study on economic attributes of precast construction method in Malaysia and found out that the method offers long-term monitoring mechanism by using life cycle costing in cost development (about 5%), the thoughts of environmental-related products are always involving huge financial burden up-front in term of financial investment (about 6%), but it offers faster ROI of a project (about 3%).

Conventional construction method consumes more wooden formwork and many numbers of labour and raw material. The long construction time is the main critical constituent toward higher construction cost. However, conventional construction method is suitable for those country where skilled labour is limited since this method does not integrate heavy machines and high-skilled technical works, where labour can be trained easily to perform the construction works such as erecting the moulds and placing the steel reinforcement. Therefore, conventional construction method is technically applicable to almost all types of building construction works since it requires low skills with easy adaptation and simple construction (Badir et al., 1998).

Waste is another serious scenario created from conventional construction method. The continuous increase in material waste has directly impacted on the operational management on site. The material loss greatly affects the productivity and causes the project to lose considerable amount of revenue. According to Begum et al. (2006), almost at least 10% of materials in the construction site is wasted in conventional design, documentaries, materials and site management. As a result, there is an increase in total construction cost of a building. In Malaysia, the precast construction method has been proven that it is better in reuse and recycle around 73% of the construction wastage. As the demand for residential development keeps on increasing, a large amount of construction waste is being produced. For instance, a typical home constructed by using the conventional construction method normally creates between 20%-30% of wastage in terms of production cost. It is estimated that 2.5 to 4 tons (about 1.5 to 2.5 kg per square foot) waste is generated. The largest component of waste material consists mainly of lumber and manufactured wood products, drywall, masonry materials, steel, and cardboard. The remainder is a mix of roofing materials, metals, plaster, plastics, foam, insulation, textiles, glass, and packaging (Dani et al., 2014). On the other hand, precast construction method optimises the use of materials which in turn causes the reduction in waste and increases site safety due to better site management and neatness (Phang, 2017).

During the construction process on site, time consumption must be well controlled to avoid the cost overhead and it is also important to consider the general expenses especially in precast construction method. It is important to supervise on crane planning and coordination on delivery to ensure no consequential delay in the onsite installation process. It is realised that the current construction industry still cannot fully surmount the significant effects on time delay. According to Akintoye et al. (2002) in the study on cost and time overruns of projects in Malaysia, it was discovered that among 359 construction projects in Malaysia, only 18.2% of the public sector projects and 29.5% of private sector projects were completed on time with an average percentage of 49.7% projects suffering time overrun and delay. It might be realised that the projects suffering delay were due to some inevitable reasons which include the problems of financing such as late payment for completed works or poor contract management; sudden changes in site conditions and design; shortage of materials supply and the most unavoidable weather conditions. In addition, a study in Hong Kong also addressed that at least 15-20% of a sample of 67 civil engineering projects suffered extra time consumption and overrun due to inclement weather on site (Miller et al., 2000). As the concept of time is money is the nature of the local construction industry, therefore, it is important to select the alternate construction method so as to minimise the root cause of the time delay such as the issue of inclement weather for site works. Phang (2017) observed that precast construction method is better in cost saving as it consumes less construction time since the construction operation is less affected by bad weather.

Construction method also affects the choice of 'materials and methods' used in construction. Total building cost will be affected significantly by the choice of construction methods. Chan (2011) conducted a study on the comparison of construction cost and choice of methods through a quantitative framework study on the construction material, labour and capital cost indices for evaluating the framework structure of the construction industry. It was found that the life-cycle cost of buildings can be reduced if the construction method is easily adopted; the involvement from large numbers of cheap labour forces; availability of abundant construction materials without the added transportation cost; inexpensive maintenance cost and lower investments on the methods used. On the matter of transportation cost, Warszawski

(1999) mentioned that transportation is the main barrier that has limited the design considerations on the size and weight of the completed precast structural components in Malaysia. The length of a volumetric structural component should not exceed 12 m. The precast component should not exceed the maximum height and weight of 4.5 m and 7 tonnes, respectively, when loaded on the trailer. The components could not enter the highway system if they exceed a height limit ranging from 4.8 to 5.1 m. Mobile cranes commonly with 20- ton, 50-ton, or 70-ton capacity maybe required for the hoisting to install the precast structural components. This may somehow increase the operational cost of the construction project. In addition, the construction development area to the fabrication plant should be within the distance of 50 to 100 km for economical transportation cost.

As for the wage rate, is the direct cost per hour paid to the workmen whereas the indirect labour costs are the payments made by a contractor on the behalf of employee. Therefore, the labour rate is the total of direct and indirect cost per hour (Davis, 2010). According to Haron et al. (2013), conventional construction method will cost more in the whole construction project cost due to the cost for labour, raw material and longer time duration of the construction project. According to Zarim (2017), the factors that determined the benefits of the precast construction method includes the labour, of which the number of labours can be reduced, easier coordination, less raids by authorities, less social problems and create more profit. Precast construction method also creates less accident, less disruption to construction time which brings more profit, offers faster construction period, faster delivery to purchasers and less interest payments to the bank. Precast components also minimise defects and gain reputation for delivering fast and high-quality products.

Lim et al. (2017) also noticed that conventional construction method is very labour intensive and unproductive. Wet works such as the fabrication of steels on site have higher wastage, creates housekeeping problems and lead to potential spalling due to poor workmanship. Quality pertaining to bulging formwork and honeycombing problems, result in abortive works like hacking and patching. Advantages of precast construction method includes self-supporting ready-made components are being used, so the need for formwork, and scaffolding is greatly reduced. Construction time is reduced and buildings are completed sooner, allowing an earlier ROI. On-site construction and site congestion are minimised. Quality control can be easier for high-precision components manufactured in the factory. Time spent in bad weather environments at the construction site is minimised. Less waste may be generated and hence more sustainable. On the other hand, challenges of precast construction method include careful handling of precast components such as concrete panels. Attention has to be paid on the strength and corrosion-resistance and leaks of the joining of precast sections to avoid failure of the joint. Transportation cost may be higher for precast components. Large precast components require heavy-duty cranes and precision measurement and handling to place in position.

As a summary, the comparative study between the conventional construction method and precast construction method has to begin with identifying the type and nature of the construction project. Next, the selection of comparative method such as cubic content estimation, floor area, and unit valuation, bill of quantities or approximate quantities depends on the level of accuracy required for the comparison. The critical elements for the comparative study include time, labour, equipment, machinery and material cost. These can be further evaluated from its design, production and construction phases. It is also necessary to break

down the critical elements further into fixed cost, time-related cost and quantity- proportional cost.

In general, the construction project total cost is determined from its project direct cost and indirect cost. Despite the investment in the precast may return on its revenue over the long term as more components are produced but many of the local contractors are still not able to adopt the precast construction method due to limited local technology and high investment capital. Time delay is a major reason for escalating project cost. Delay in the completion of a project will likely incur provision for the liquidated and ascertain damages (LAD) payment of a specified amount in breach of contract. The longer the delay, the higher the provision will be.

As mentioned in the preceding discussion, precast construction method reduces the costs on labour and wastage. The profit margin of the method will be less volatile and visible if the cost elements are combined with better project delivery in term of time. The adoption of precast construction method enables better management of building material and hence overcome the supply shortage problem in building material such as sand, aggregates, and ready-mixed concrete. As the increase in demand over supply can raise the construction cost which can burden builders, precast construction method can also stabilise the building material prices by reducing construction materials used. The critical problems on choosing precast construction method greatly depend on the availability and standardisation of precast components. With the availability of standard components, it will further develop a standard and more competitive price and quality products and hence make it more affordable. Apart from that, the ISO certification of precast manufacturers will boost buyers' confidence in the quality of the product.

SUMMARIZE OF PROBLEMS OF IMPLEMENTATION OF PRECAST BUILDING CONSTRUCTION METHOD

To date, conventional construction method still remains the primary choice of construction method as compared to precast building construction method. Conventional building construction method is widely adopted among the construction practitioners especially the private sector in small scale housing project. It is due to the nature of project total cost is the primary concern for the choice on construction method of which aims to raise the profit turnover.

According to the statistics recorded in year 2016, the total construction contracts in Malaysia is RM124.96 billion. The public sector accounted for 23% of contracts values and the private sector undertook the remaining 77% of the contract values. The public sector took a total of RM29.07 billion involving the residential projects (RM0.60 billion, 2%); non-residential projects (RM6.12 billion, 21%); and infrastructure projects (RM22.35 billion, 77%). Comparatively, the private sector undertook the larger contract amounts with the total of RM95.89 billion consisting residential projects (RM28.62 billion, 30%); non-residential projects (RM32.07 billion, 33%); and infrastructure projects (RM35.20 billion, 37%) (Elias et al., 2017). Hence, the private sector is the major player in the construction industry especially in housing projects. However, the adaptation of precast construction method in the private sector is extremely low at 14%, as compared to 69% in the public sector achieved in the same year (Department of Statistic Malaysia, 2016).

The precast building construction method remains lukewarm since there still exists the ambiguity in term of the interpretation of project total costs. Research findings from previous researchers have polarized on this issue. Most of the research works done previously were focused on comparative study on particular types of structural components and considered the single component for cost-determinants. For instance, the research done by Yong (2010) to compare the material costs on slab and beams constructed by using conventional and precast construction methods cannot fully used to compare the economic performances between both construction methods. In addition, the comparison methods on which to breakdown the project total costs also highlight the extent of accuracy of the comparative results and to ensure the parameters of the comparative study are consistent and obtain homologous comparison. Therefore, previous research findings obtained from Hafiz (2016) on the comparison of material costs between precast half slab and conventional suspended slab tackled from unit cost per floor gross area can be presented into more delicate way. Regarding on this, Jabatan Kerja Raya (2017) stated that approximate quantities is the most accurate method for estimating the project total costs. In between, the cost-determinants have to include all the direct and indirect costs.

In addition, it is hard to convince the construction practitioner to practice the precast building construction method in low rise building project mainly on housing project since there remain disputes findings on the cost effectiveness of precast building construction method in low-rise housing project. As the previous research findings stated that precast building construction method only raises the costs effectiveness in large scale project with building projects more than 5 storey (Research Design and Standards Organisation, 2014; Akash et al., 2016).

COMPARATIVE STUDIES ON CONVENTIONAL AND PRECAST BUILDING CONSTRUCTION METHODS

This section reviews the comparative case studies between the conventional and precast construction methods in building projects. The outcomes of each of the comparative studies are also presented in this section.

Overview on Precast Building Construction Methods Worldwide

The precast construction method is recognised worldwide. According to Jaillon and Poon (2009), the precast construction method has been widely utilised in the developed countries such as Japan, United States, United Kingdom, Sweden, Netherlands, Australia, Singapore, and Hong Kong in the early of 1970's to fulfil the high housing demand due to rapid increase in population.

In Asian countries, for instance, the precast industry in Japan started in the 1960's since the usage of precast components and succeeded to represent about 20% of the housing projects in the year 1999. Majority of the precast component being used is the steel framing system (73%), the wood framing system (18%) and reinforced concrete framing (9%). In Singapore, the development of the precast construction industry encountered failure at the early stage when the first precast construction method was launched in 1963 using precast panels and other precast systems to construct 10 blocks of standard 16-storey flats. The project experienced numerous technical and management problems and had to be solved by the conventional

method. However, the precast construction industry reincarnated in year 1979 and yet introduced many types of precast systems with spectacular growth. The precast construction industry in Thailand developed rapidly due to labour shortage and high interest rate (Jaafar et al., 2003).

In United Kingdom, about 165,000 precast concrete dwelling units had been built ranging from single storey bungalow to large high-rise buildings in year 1960. Precast concrete represents about 25% of the market for cement product. The precast 'tilt slab' was first introduced in Australia in the early of 1950s to afford the number of accommodations in Canberra. Germany is well recognized for the area of precast internal and external wall as well as roof panel since year 1998. In United State of America, precast construction method emerged in the early of 1930's through the construction of prefabricated steel house by General Homes, Inc. However, the method faded in the early of 1930's due to uncompetitive price, high capital and inconsistent local codes. Fortunately, the trend reversed after the Second World War due to the need to resolve critical shortage of houses. In 1999, prefabricated housing gained substantial market share with 30% of housings using this construction method. Although most low-rise housing uses timber frame, concrete precast system is being used intensively, particularly in areas that are vulnerable to environmental hazards such as hurricanes and tornados (Jaafar et al., 2003).

In Malaysia, precast concrete beams and columns were first introduced in 1960's in a high-rise apartment project of 17 floors. Within year 1995 to 1998, the success of practicing precast construction method in Malaysia can be traced back from the symbolised structures, including the Petronas Twin Tower, the Light Rail Transit, and the Bukit Jalil National Sports Complex. Despite the fact that precast construction method has been introduced in the Malaysia construction industry in the past five decades ago, the method still receives relatively low adoption particularly in the private sector as compared to the developed countries. In terms of technology, while Malaysia is still using mechanical machines, Japan has advanced to robotics in the production of the precast components. Although statistics are not readily available, in 2002, most precast components in Malaysia were found to have originated from the U.S., Germany and Australia with market share of approximately 25%, 17% and 17% respectively. Malaysia-owned precast manufacturers accounted for only 12%. This indicates that there is a considerable room for improvement in the area of research and development of precast construction method in Malaysia (Malaysia Equity Research, 2014).

Cost Comparative Case Studies on Fully Precast Building System and Conventional Construction Methods

In India, Aakash et al. (2016) had carried out a comparative case study on a double storey residential building with precast and conventional building construction methods to review on the role of time, cost, quality and productivity of the precast system. The total duration for both conventional and precast construction methods were divided into substructure, superstructure and finishing works whereas the cost comparison for the structural components was done by categorising it into conventional reinforced concrete components or precast structural components. Results have shown that precast construction method came out to be 23.1% lesser in costs and saved construction time up to 50% compared with the conventional method. The economic aspects in terms of lower cost and shorter time improve the productivity and the quality is secured through the precast products. The particular saving in construction costs may

be owing to the design of the building layout with high repetition and standardised precast components.

According to Amir et al. (2015) on economic comparison of industrialised building system and conventional construction system with the same initial investment and time by using building information modelling, the case study for single-story building was modelled by using the Revit Architecture 2013 into two types of plans, one is for precast construction method and the other one is for conventional construction method. The data were collected based on Malaysian rules and reasonable assumptions on unit price of materials. Based on the two modelling, the quantity take-off was calculated and the work breakdown structure (WBS) was created to estimate the project total cost. Microsoft Excel software was employed by using the visual graph based on the break-even point (BEP) analysis, ROI and profitability of each project. The results show that building cost in precast method is more expensive as compared to conventional method by 41%. However, precast construction method can save up to 26% on materials (less wastage) as compared to conventional construction method. These findings indicate that precast construction method is only more economical compared with conventional construction method when more than 200 units of precast structural components are implemented in the projects.

A separate study was conducted by Yong (2010) on the cost comparisons for conventional and precast building construction methods in Malaysia to determine the effects of wages and material costs on the price of the selected method. The materials or components costs were obtained from the precast manufacturers and the costing rate can become the reference costs for precast construction projects in the states of Selangor, Perak and Federal Territory of Kuala Lumpur. The case study focused on proposed hostel blocks for an institution of higher learning in the state of Perak, Malaysia. The builder was obligated to construct 4 blocks with implementation of the precast construction method and the remaining blocks were constructed by using conventional method. Each hostel block had the same total floor area. The cost estimates were done based on each respective set of construction drawings for the two construction methods. The conventional construction method used the cast-in-situ reinforced concrete structural frame with slab and beam arrangement whereas the proposed precast construction method used precast columns, precast inverted T beams supporting hollow-core precast prestressed planks of which the planks were eventually topped up with an 80 mm structural screed. The comparison of the structural material costs showed that the precast structural components are 64% more expensive than the conventional cast-in-situ reinforced concrete structures. In contrast, the wage for precast labour is 39% cheaper than conventional on-site labour. Therefore, it can be concluded that the lower labour costs consumed in the precast method still cannot substitute the conventional method due to higher precast material costs.

In a case study on a residential building in Melbourne with utilised precast prestressed hollow core planks with precast prestressed inverted T beams, Yong (2010) identified a number of significant cost differences between precast and conventional building construction methods. This case study on the building at Octavia Street in the suburb of St. Kilda includes a single level basement and two above ground levels providing a total built-up area of 1,154 m^2. The walls were also precast concrete panels. A cost estimate of the structure was obtained from the builder for the supply and installation of all the precast components. In order to compare the two construction methods, an alternative post-tensioned slab and beam system was worked out.

The purpose of adopting a post-tensioned band beam and slab methods was to ensure that the same column and beam layout could be used for both the precast and post- tensioned systems. The results have shown that the post-tensioned conventional cast-in situ slab and beam option costed approximately 30% more than the precast construction method. This was mainly due to higher material costs and doubling of the conventional method labour cost. The cost for crane rental was similar due to the requirement of higher capacity cranes for lifting of the precast components compared with lower capacity cranes for longer time duration for the conventional construction method.

From the above case studies by Aakash et al. (2016) and Amir et al. (2015), it can be seen that designing the building layout with maximum number of repetition and standardised precast structural components can help in lowering the precast construction costs. While the cost differences in the two case studies in Australia and Malaysia by Yong (2010) can be interpreted as the vast difference in wage structure in the two countries. The conventional construction labour force in Australia usually involves predominantly local and highly skilled labour, therefore attracting premium wages. In contrast, the conventional construction labour in Malaysia consisted of foreign workers with lower wages. In conclusion, construction players in a developed country with high labour wage rates usually switch to higher capital inputs such as precast construction method in order to decrease labour input to minimise costs as opposed to conventional construction method. On the other hand, construction players in a developing country refuse to practice precast construction method because of easier access to cheap foreign labour in conventional construction method. As a conclusion, the practice of precast construction method is still considered as localised since it is always limited by the local practice's norm and regulations. Besides, it may be affected by the location factors such as the transportation cost, availability of raw materials and labour force. Therefore, future studies regarding on the comparative study between the conventional and precast building construction methods should probe into these parameters particularly on the building design specifications and labour costs.

Cost Comparative Case Studies for Precast Slab and Conventional Building Construction

Time is another crucial element in the discussion on comparative studies between building construction method. As stated in the study of Hafiz et al. (2016), the study was focusing on the cost comparison of precast half slab and conventional suspended slab for a school construction project based on technical data collection and analysis on material costs. Two school projects which are SMK Idris Shah at Kinta in Perak and SMK Tinggi Klang in Selangor had been selected for the case study. The method to calculate the floor gross area with only the ground floor was used for the comparative study. The cost was estimated based on the floor area by multiplying its width and length and computed by using the cost per square metre by taking the assumption on material cost from the bill of quantities. Comparison was carried out through the construction drawings and work programme. The results have shown that precast construction method came in overall lower technical price at about 11.9% as compared to conventional construction method but it has shown higher price particularly on precast half-slab components as compared to conventional slab concrete. Besides, the study also aimed to determine the perception from a total number of 110 industrial players on precast and conventional construction methods through questionnaire surveys. Most respondents gave feedback that precast method can reduce the construction cost and time. The results obtained

also suggested the correlated relationship between the time factor and overall construction costs.

Construction Method – Comparative Case Studies on Precast Wall Panel and Conventional Building Construction

This part reviewed some research studies which were focused on the integration of precast wall panel in building construction and the advantages raised form its usage. According to Rajendra and Vivek (2015) on the case study on conventional and fast track construction techniques, it was found that precast and cast-in situ formwork construction methods resulted in cost saving of 37% for monolithic construction and 53% for precast construction method due to early completion of project. The study was conducted based on the investigations on a police quarters at Mysure, India with aspects such as quantity of materials required, cost and time duration with cast-in situ formwork construction, precast panel system and conventional construction method.

Sivapriya and Senthamilkumar (2014) had carried out a building cost comparison study on precast and conventional building construction through a case study on school project with total built up area of 18,800 m2 with only the ground and the seventh floor constructed with the precast wall panel components. It was concluded that the project overall cost needed for precast panel building construction was reduced by 20% as compared to conventional method. This was mainly due to the reductions in formwork by 75%, access scaffolding by 75% and reliance on wet trades by 90%. Besides, the total cost of an architectural precast concrete wall has been lowered by taking full advantage of precast concrete portion.

Asiah et al. (2012) had carried out a study on adaptable housing of precast panel system in Malaysia. The methodology for data collection used in this research was by case study and questionnaire survey. The paper identifies the potential solutions to deliver quality housing for Malaysians as well as to solve and ever harmonising the architectural design with the innovation of precast panel system in construction. The questionnaires were distributed to the tenants of teachers' quarters in the urban, suburban and rural area of Selangor and Perak. The teacher's quarters which were constructed during 1998 to 2002 remain as the biggest housing in Malaysia constructed using precast panel system. The research examined the needs and satisfaction of residents for every internal space of the quarters such as the living area, dining area, kitchen, bedroom, and bathroom. The outcomes of the study showed that there are two innovations in the project which are the Plug and Play or Support and Infill. As a conclusion, the application of precast building construction method allowed flexibility in architecture facilitated renovation in the building.

Kow (2017) reviewed on a case study of 10 storey apartment, Residential Seri Jati Apartment in Setia Alam with 948 units of 6 blocks in a single-phase development as shown in Figure 3. The construction system for the building project is shown in Figure 4 of which the building project involved the conventional construction method with foundation, ground floor, transfer beam, and reinforced concrete slab. The precast construction components included prefabricated steel roof trusses, precast walls for roof, precast load bearing walls, precast non-bearing walls, precast staircases and landing slabs, precast lift core walls, precast bathroom slab and precast air-conditioner ledges. Scoring point is the use of precast structural frames with in-situ concrete floor using reusable system formwork and use of precast walls following MS1064

vertical and horizontal repetition. The advantage on the choice of construction method in this project is that the project has high degree of repetitions for both horizontal and vertical plan. Architectural and structural designs with precast intention to capitalise on precast advantages as it gives high economy turnover of scale with more than 900 units of apartment with a single unit layout. Construction logistic is fully considered at planning stage such as the wall layout, work sequencing, crane's capacity and movement. The disadvantages of the project are brickwork and plastering in stand-alone amenities building, box-out for M&E services and kitchen or yard walls as it is non-compliance in Modular Coordination for structural elements and architectural design input. As a conclusion, an exciting external facade with different architecture features reduces the monotonicity of the internal repetitive layout. Steel moulds provide consistent quality in architecture features. No columns and projected beams provide consistent square in shape and consistent quality.

Figure 3. Residential Seri Jati Appartment, Setia Alam

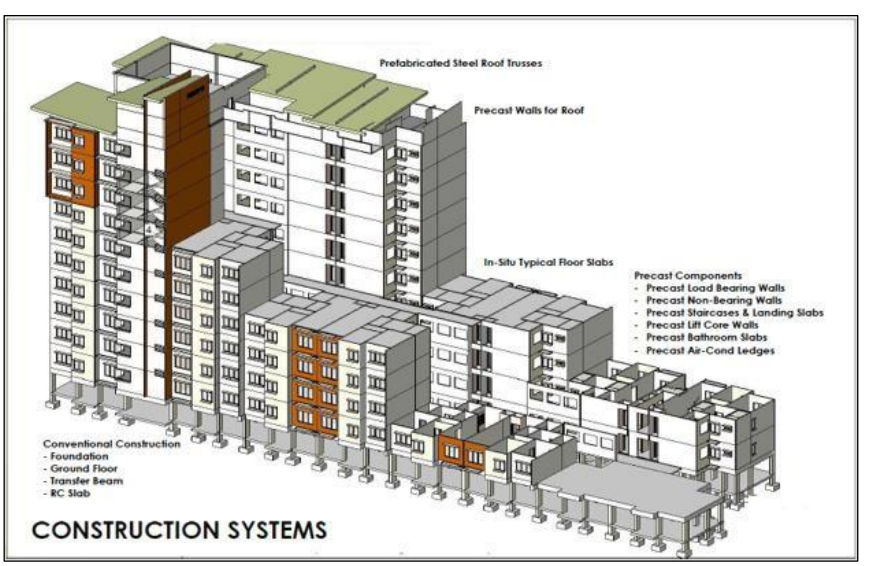

Figure 4. The Construction System for Residential Seri Jati Apartment, Setia Alam

Based on the research studies done on the comparative case studies on precast wall panel and conventional construction method, it was found that result outcomes have shown the ability of the precast construction method to overcome the technical issues and make renovation works feasible, but it still has deficiency in term of its design input. The use of precast components is proven to lower the project cost as it shortens construction time and saves wet works such as the fabrication and installation of formwork and steel reinforcement. It is, however, the cost saving gives rise to ambiguity as the cost elements for comparison of precast components is not fully described and explained especially the transportation and installation costs.

Summary of Previous Research Findings

Table 1 analyse the summary of research findings in case studies, building projects or components which have been compared in the previous studies.

From the analyse, it is crucial to understand thoroughly the comparison components prior to obtain the desired level of accuracy of anticipated comparative studies between the conventional and precast construction methods especially in its overall total cost of construction. This is to assess both the general perspective overview on the growth and cost-influencing factors and the particular comparison between the conventional and precast systems used in the case studies.

The comparative study on the general perspective overview on both the precast and conventional methods are extensively done by the researchers. The complexity of the practices in the local construction industry is dealt with customising onsite production and resources as well as schedule driven. Precast construction method is viewed as an alternate method to improve the quality and productivity of the projects through better or less machinery, equipment, materials and extensive project planning. Factors including design, construction materials, safety and risks, project total time, environmental impacts and availability of local skills will ultimately translate into construction project total cost directly or indirectly. Therefore, the critical elements to identify the comparison between the pros and cons of both construction methods can be summarised into the comparison on time consumption, operational management, and technical feasibility which can significantly influence the project total cost consumption.

From the extract of comparative case studies done by the researchers, it can be concluded that the precast construction method is still in concern for its higher direct cost for small-scale projects and the precast construction method in Malaysia is at a standstill while most project implemented the precast construction method by selecting only a particular system or partial-precast such as precast slab, wall-panel or beams instead of fully-precast construction.

Table 1. Summary of Literature Reviews

Author	Research Topic	Research Methodology	Findings
Yong (2010)	Effects of wages and material costs on the price of the selected method	Case studies -Compared on slab and beam	Precast were 64% more expensive in materials but 39% cheaper in labour costs but still higher for precast in overall.
Asmah et al. (2012)	Level of awareness of the Contractors (Grade 5-7) on IBS In Sarawak Construction Industry	Questionnaire Survey	56.1% never involved in precast project.
Lou and Kamar (2012)	Adoption of precast in Malaysia construction industry	Case Studies - Critical success factors	Key Factors: Efficiency
Amir et al. (2015)	Economic comparison of precast and conventional construction methods	Modelling - Revit architecture 2013 into two types of plans, one is precast with another one is conventional, assumptions on unit price of materials.	Precast more expensive by 41% and economical when more than 200 units of precast structural components were implemented in the projects.
Hafiz (2016)	Cost Comparison for Precast Half Slab and Conventional Suspended Slab in term of Material Costs.	Case studies -Method to calculate floor gross area with only the ground floor was used for the comparative study.	Higher price particularly on precast half-slab components as compared to conventional slab concrete.
Construction Industry Development Board (2016)	Critical Elements for Comparative Study between Precast and Conventional Construction Methods	Case studies on project management on precast construction projects	The relationship between the time, labour, materials and costs are always interrelated and cannot be analysed separately
Jabatan Kerja Raya (2017)	Critical Elements for Comparative Study between Precast and Conventional Construction Methods	Case studies on comparative studies between conventional and precast building construction method	Approximate quantities is the most accurate method for estimating project total cost.
Lim et al. (2017)	Critical Elements for Comparative Study between Precast and Conventional Construction Methods	Case studies on types of precast construction projects	Study on precast construction projects can be divided into 3 categories which are the fully precast project, partially precast projects, and selected components precast projects.
Kow (2017)	The advantages of choosing the Precast Building Construction Method	Case study of 10 storey apartment, Residential Seri Jati Apartment in Setia Alam with 948 units of 6 blocks in a single phase	Architectural and structural designs with precast intention to capitalise on precast advantages as it gives high economy turnover of scale with more than 900 units of apartment with a single unit layout.

FUTURE PERSPECTIVE OF THE PRECAST BUILDING CONSTRUCTION INDUSTRY IN MALAYSIA

Regardless of the varied cost influencing factors identified in literature, to date, there is still no literature available to clearly figure out and break down the detailed comparison between a fully-precast and fully-conventional construction project in Malaysian construction industry as prior research focused on the cost breakdown involving the precast and conventional construction methods. As for the stated case studies reviewed on other countries, they can only be used as supportive proves or relevant causal relationships. In fact, the construction project total cost is influenced by the difference in local practices and regulations

such as the government and construction industry policies, availability of local resources such as the raw materials, labour and capital.

This paper suggests that the comparative study between the conventional and precast construction methods should be carried out through a clearer prototype module or otherwise a fully-precast project by comparing its economic aspects among both the precast and conventional construction methods. Therefore, stakeholders in multinational projects which include the contractors, investors, designers, financial and government organisations should be equipped with enough knowledge on the choice of construction method during the planning of projects in different environments so as to give advice on project total cost at the feasibility stage and prior to bidding and construction.

CONCLUSION

It is crucial to understand thoroughly the comparison components prior to obtain the desired level of accuracy of anticipated comparative studies between the conventional and precast construction methods especially in its overall total cost of construction. This review paper assesses both the general perspective overview on the growth and cost-influencing factors and the particular comparison between the conventional and precast systems used in the case studies.

The comparative study on the general perspective overview on both the precast and conventional methods are extensively done by the researchers. The complexity of the practices in the local construction industry is dealt with customising onsite production and resources as well as schedule driven. Precast construction method is viewed as an alternate method to improve the quality and productivity of the projects through better or less machinery, equipment, materials and extensive project planning. Factors including design, construction materials, safety and risks, project total time, environmental impacts and availability of local skills will ultimately translate into construction project total cost directly or indirectly. Therefore, the critical elements to identify the comparison between the pros and cons of both construction methods can be summarised into the comparison on time consumption, operational management, and technical feasibility which can significantly influence the project total cost consumption.

From the extract of comparative case studies done by the researchers, it can be concluded that the precast construction method is still in concern for its higher direct cost for small-scale projects and the precast construction method in Malaysia is at a standstill while most project implemented the precast construction method by selecting only a particular system or partial-precast such as precast slab, wall-panel or beams instead of fully-precast construction.

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