PREFABRICATION IN THE SINGAPORE CONSTRUCTION INDUSTRY

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Abstract: Singapore's limited resources have caused severe labor shortage and brought adverse impact on the construction industry. Prefabrication, the crucial part of the integrated construction automation processes, has appeared to be the ideal and most practical way to sustain the long-standing strategy of reducing the reliance on labor resource. In this paper, the potential of prefabrication in resolving the human resource problem in the Singapore construction industry is discussed. It will introduce how the Singapore government has over the years implemented prefabrication into the local construction practice. The issues faced by the local industry will also be presented.

Keywords: Labor shortage, Industrialization, Construction productivity, Prefabrication technology.

1. HUMAN RESOURCE PROBLEM IN THE SINGAPORE CONSTRUCTION INDUSTRY

Construction industry has distinctive features from other industries. Unlike the mass production industries, the large scale, open air job site and extensive fragmentation in the construction process make it relatively more difficulty to introduce advanced technology into the industry. This has caused low productivity and poor industry image in the construction industry.

Economic growth in Singapore caused greater demand for better and more efficient infrastructure. Demand of workers increased as more new construction works come up. However, with rising standards of living and affluence, Singaporeans have, over the years, shunned the industry as a potential career. In the early 1960s, Singapore government had already foreseen the labor shortage problems, thus permitting the inflow of foreign workers into the country. Over the past decade, foreign workers were dominant at almost all of the construction trades. In 1998, the foreign component of the total construction force is 81.2% (Table 1).

The revolving pool of foreign workers has over the years served as a vital supplement to the indigenous workforce. It also served as a buffer against sudden fluctuations and enhances the ability to take advantage of unanticipated surge in world economic trend. While foreign workers may have overcome labor shortages in the industry, the problem of low productivity associated with the readily available pool of cheap foreign labor prevails. As a result of this cheap labor, there are no incentives for contractors to improve construction methods by introducing technological advancements. Construction productivity has declined over the years. Lower productivity has resulted from longer construction times and an unprofessional image. Such a situation is exacerbated by the fact that the bulk of the foreign workers in the industry have little or no skills. Presently, the industry still lacks key professional proficiencies, even though there has been an increase in the number of skilled foreign workers. These cheap and unskilled foreign workers have also given rise to a lot of problems in the construction industry. These include malpractice in the treatment of foreign workers by employers and poor safety records.

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The main issue of the human resource problem in the Singapore construction industry is the industry's unattractive image and the social dislike for strenuous physical activity in the open hot environment. Attractive training package, increasing earnings and ready job opportunities have not eased the situation. It will be even harder to recruit personnel with the rising of living standards and expectation of the population. So attempts to reduce the construction industry's dependence on labor, a long-term strategy in Singapore, appear the most viable solution to the human-resource problem [1].

Table 1: Percentage of Foreign Tradesmen in the Construction Industry in 1998

Trade	Foreign Component			
	Certified skilled	Semi-skilled	Unskilled	Total Workforce
Civil Engineering	73.1	81.5	89.7	81.5
Structural Trades	86.3	86.5	94.2	89.1
Finishing Trades	64.4	72.0	90.7	74.2
Building Service	54.2	70.3	92.5	73.0
Plant & Equipment Operator	32.0	67.6	65.9	39.9
General Worker	NA	NA	89.8	89.8
Total	66.0	77.1	90.9	81.2

Source: CIDB [2]

2. POTENTIAL OF THE PREFABRICATION TECHNOLOGY

2.1 Benefits of prefabrication

Industrialization in the construction industry involves the process of standardization of the construction components and then the "mass production" or prefabrication of these components in the prefabrication factories. Though there is still room for large improvement due to the distinctive features of the construction industry, prefabrication, the crucial part of the industrialization process in the construction industry has proven successful in some developed countries such as Finland and Japan, that have also encountered labor shortage problem in the construction industry. Prefabrication is not new for Singapore. It also has achieved success in the pilot test in the public sector and has great potential to resolve the human resource problem and improve the productivity in the construction industry of Singapore as a whole.

Based on the experience of application, benefits of prefabrication technology are:

1. shorter construction time
2. better quality of construction products
3. saving in construction site labor

Compared to the manual operation on site, more precise handling of mechanization in the plant will contribute to better quality construction products; Greater speed can be achieved due to the parallel operations both on site and in the plant. These benefits will eventually bring about greater improvement to the total productivity and hence the industry's image.

Saving in construction site labor results from the transfer of construction work to the prefabrication plant where relatively higher mechanization level is applied. Though there will be extra labor needed in the works of erection, connection and jointing of precast components, and the fabrication in the plant as well, altogether, using prefabricated elements will lead to 40%~60% saving of the total labor on site. Labor savings will be even greater if prefabrication is extended to a wide range of traditionally built parts [3].

Beneficial result from application of prefabrication depends very much on the availability of skilled labor but also depends on the weather and other site conditions. Singapore's scorching temperature and frequent precipitation had not only kept the local people from entering the construction industry but also impede the smooth progression on site. More prefabrication work means more work conducted under the more comfortable in-house environment, which is preferred by the local people. Production process under the factory environment will be better controlled and thus will proceed more smoothly. Given the special situation in Singapore, the benefits of prefabrication appear to be more notable.

2.2 Potential areas of application

The usage for site labor varies with the progress of the site works from structural works, architectural to mechanical and electrical works. In order to achieve greater savings on site labor and productivity improvement, labor intensive areas of work should be identified, and the application of prefabrication should be focused on these greater potential areas.

Table 2 shows the distribution of site labor at various stages of typical projects in Singapore with conventional construction methods.

Table 2: Usage of workers

Type of work	Usage of workers

	(percentage)
Structural	50
Finishing	30~35
Mechanical & Electrical	15~20

Source: CIDB [4]

Structural work is the most labor intensive, consuming about 50% of the workers' time. Thus, there is great potential for labor savings in this area. The major trades in structural work are formwork carpentry and steel reinforcement fixing. These trades are more laborious and exposed to the open-air environment. With the prefabrication of structural components, labor input will be decreased substantially due to mechanization in the precasting plant.

Architectural and finishing work includes a mixture of crafts and wet trades. Bricklaying, plastering, and tiling are some of the more labor-intensive architectural trades. Prefabricated walls completed with finishes will reduce labor content for these trades. Usage of high quality lightweight blocks will reduce the thickness of plastering. Mechanized method of plastering is another option for cutting down labor content. For internal walls, drywall methods are much easier and quicker to install [5].

Mechanical and electrical trades are basically dry or assembly trades. Relatively more prefabrication has been applied in its distribution systems, so there is little potential in reducing manpower usage in this area through prefabrication.

3. GOVERNMENT'S PROMOTION

Precast components had been used in the Singapore construction industry in the 1980's. Realizing the potential of prefabrication in resolving the human resource problem in the construction industry, the Building and Construction Authority (BCA) started a five year program in 1992 to promote the usage of prefabrication to the local industry. BCA aims to increase the usage of prefabricated concrete components from the current level of 8% to 15% by the year 2005.

3.1 Buildable Design Appraisal System (BDAS)

Since the upstream design decisions have significant impact on the downstream construction methods, buildable designs had also been promoted by BCA to the local industry since 1992, especially in the public sector. An appraisal system, The Buildable Design Appraisal System (or BDAS), which is used to assess the impact of the design on the site labor usage and productivity was also designed and implemented by BCA. A five-year pilot test of this system was carried out in the public sector.

BDAS looks at the design and computes the extent to which the principles of standardization, simplicity and single integrated elements are found. It covers the structural system and the major architectural components such as external and internal walls, doors and windows [4]. Points are allocated according to the distribution of workers in traditional trades. Structural systems are allocated 50 points, and architectural system is given 30 points, the remaining points are allocated to other structural, architectural and M & E buildable features.

The appraisal system results in a 'Buildability Score' of the design. Normally, with higher buildable scores, it will encourage more usage of prefabricated components that may lead to more efficient labor usage during construction and higher site labor productivity.

Success had been achieved in promoting prefabrication and buildable designs in the public sector. However, the private sector lags far behind. The government is strongly promoting the concept to the private sector in the coming years. In January 1999, the buildability requirements were made mandatory by the government for new buildings as part of building plan approval. This mandatory requirement had been applied during the bidding of public sector projects before. A code of practice was released in March 2000, in which the minimum buildability scores for different categories of building projects were specified.

3.2 Publications and Training

Publications that aim to familiarize the local developers and engineers with the prefabrication technology and components were also released over the past few years. These guidebooks provided the general information and benefits of the prefabrication technology. Areas where prefabricated components can be used were also identified. BCA also led a program to introduce greater standardization of major components used in various types of buildings. The CIDB Guide to Precast Concrete and Prefabricated Reinforcement for Buildings is intended to standardize the key components to increase the usage of precast molds. Similar guides were also given on dry walls and other prefabricated components.

In order to train the workers to be familiar with the efficient construction methods associated with prefabrication components, the Construction Industry Training Institute (CITI) had conducted training programs such as precast concrete components erection, lightweight concrete precision blocks installation, drywall installation and mechanized spray plastering. This will lead to higher productivity gains and lower level of labor inputs.

4. STATE OF PREFABRICATION IN THE LOCAL INDUSTRY

4.1 General situation

With the BCA's effort to promote the fabrication technology, the industry is now generally aware of the benefits of prefabrication. A five-year Buildable Design promotion program started by BCA in 1992 for the public sector has adopted buildable designs and prefabrication. Despite this, the overall outcome is still not satisfactory.

Consumption of precast components had nearly doubled from 1993 to 1998. The public sector has been the engine of this growth. More than 80% of the precast consumption is from the public sector. The precast level for the public sector is 28%. The total level for the industry is still low at 8% (Table 3).

Table 3: Consumption of cement and precast level

Year	1993	1994	1995	1996	1997	1998
Cement ('000 tons)	258	240	312	354	521	472
Precast level (% of concrete)	6.90	5.80	7.10	6.40	8.20	8.00

Source: BCA [6], Tan [7]

This is due to the slower implementation of buildable design in the private sector. Evidently, the public sector projects have higher buildable scores due to the extensive implementation of buildable designs and prefabrication (Table 4). In accordance with the buildable scores, the productivity of the public sector is much higher than the private sector (Table 5).

Table 4: Buildable scores in the construction industry

Year	1993	1994	1995	1996	1997	1998
Public sector						
HDB	70	70	72	74	77	78
Private Sector						
Residential	50	52	52	53	50	53
Commercial	60	62	62	61	63	62
Industrial	59	60	64	63	64	62
Institutional	NA	59	59	60	64	63

Source: BCA [6]

Table 5: Productivity statistics in m^2/man-day

Year	1993	1994	1995	1996	1997	1998
Public sector						
HDB	0.66	0.66	0.66	0.66	0.66	0.69
Private sector						
Residential	0.21	0.22	0.18	0.21	0.20	0.22
Commercial	0.24	0.24	0.25	0.22	0.27	0.26
Industrial	0.40	0.36	0.37	0.40	0.40	0.45
Institutional	0.26	0.22	0.23	0.24	0.29	0.26
Industry average	0.31	0.31	0.32	0.34	0.36	0.37

Source: BCA [6]

Currently, there are 37 precasters in the precast industry. In 1996, among the total 33 precasters, only 5 managed to handle turnovers of more than S$30 million per annum (Figure 1). Actually, the top 5 companies account for almost 79% of the market share [7]. The investment and output of the majority of the precasters are not satisfactory. However, most of the precasters plan to expand due to their optimism about the future demand for prefabrication components.

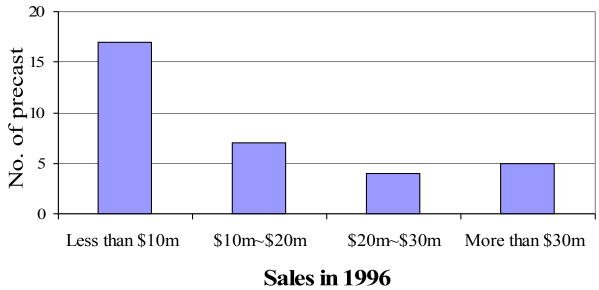

Figure 1: Output of precasters
Source: Tan [7]

4.2 Product development

With the surge of the building program in Singapore, prefabrication components have developed to a wide range of varieties.

Precast staircases, refuse chutes, water tanks, lightweight partition panels are the initial development of precast components in Singapore. Precast beams and columns have been applied in some of the public institutional projects. The latest innovations include precast household shelter doorframes, lift walls, ferrocement roof slabs and footings etc. These sections of the building are difficult and time consuming to cast on site. They are precasted in the factory and then erected on site. These components are known as the value-added products or standardized components.

Prefabrication has also been introduced to the area of reinforcement fixing. Examples of prefabricated reinforcement includes welded wire fabric, prefabricated link cages and prefabricated full cages (links and main bars). The Housing and Development Board uses welded wire fabric, prefabricated link cages and full-prefabricated beam cages extensively in their projects. Areas where prefabricated reinforcement can be used are actively identified and the use of standardized meshes and cages are conscientiously promoted [8].

4.3 Factors impacting on the development of prefabrication

Prefabrication technology has proven its benefits in labor-savings, quality, and productivity. Its implementation in Singapore has progressed a lot during the past decade. However there are several important factors that has impacted the implementation of prefabrication in the past and will also influence the future development of prefabrication as well.

- Unfamiliarity

One of the reasons that impede the wide implementation of prefabrication technology in the local construction industry is that the industry is still not familiar with the buildable designs and prefabrication technology especially in the private sector. The conventional, less productive designs is still preferred because of cost. More effort such as design planning and rationalizing are needed in the initial stage of the application of prefabrication. But the designers normally are not concerned too much with the know-how of the buildable designs and the prefabrication technology, as this often requires additional effort.

- Higher initial cost

Implementation of prefabrication technology may initially give rise to higher construction cost. The general opinion of precasters is that the initial payment is high due to investment in plant facilities. Since it is a requirement to possess permanent fabrication facilities or yards to fabricate concrete products, the investment in plant facilities that includes machinery is rather costly. In addition, maintenance cost of the machinery is very high. In some cases, where the construction contractors set up their own precast yards near the construction sites and produced the precast components themselves, the start-up cost will be a heavy burden for these contractors. They will ask for a higher preliminary progress claim, which can amount to about 15% of the total contract sum.

- Insufficient standardization

For prefabricated construction, the repetition of components affects the productivity of site installation. Too many types of components with low repetition slow down factory production, site installation and increase installation complexity. Carried to the extreme, prefabrication could be worse than conventional construction. Currently, lack of standardization in the industry is an important issue to be addressed for the successful implementation of prefabrication technology. Discussion with precast components manufacturers and contractors was held so as to determine the minimum repetition required for economical production of precast components. Precasters generally agreed the minimum repetition should be 20 [4].

- Poor coordination and communication

Application of prefabrication needs the integrated and well-coordinated efforts by the various disciplines involved. Poor coordination and communication has brought harmful effect to the implementation of prefabrication in the local industry. Insufficient design detail and delayed delivery of precast components by the precast factory etc. are now very common in the industry. These situations have resulted in many disputes and problems when the construction process proceeded later on.

- Expertise

In term of expertise and technology, there are few entry barriers for the contractors to join the precast industry, since the precast production is still labor-intensive compare to other developed nations such as Japan and Finland.

The main raw materials used in the precast production are cement, sand, granite and concrete, which are easily provided from local sources or Malaysia. The molds and machinery are usually obtained from overseas through local agents.

Many of the precasters still use relatively labor intensive methods of production. Few have taken full advantage of automated casting, mechanized curing and round the clock production. Computer Integrated Manufacturing (CIM), which is commonly used in European precast firms, is not used in the Singapore precast firms. BCA estimates that the precasters are operating at less than 80% of their capacity. The throughput is also less than optimum as components are stored for long periods due to poor coordination and contractors' inability to keep to installation schedules [7]. In the area of research and development (R&D), most precasters expressed that they hardly spent any money in this area as there is no necessity to engage in sophisticated technology in the production [9].

The level of precast design expertise is also inadequate. Designers often leave most of the details to the precasters, but only some precasters have in-house designers and can provide extensive consulting for the projects. This has retarded the growth of the prefabrication industry.

- Land availability

Feedback from the precasters in Singapore showed that the availability of land for expansion is their greatest concern. Land use is generally inefficient. Most of the precast factories are single-storey factories with plenty of space for storage. As a result, the average annual output of the precast sector is only about 1 cubic meters per square meter of land. More innovative and efficient designs of precast factories are needed, e.g. multi-storey. Otherwise the high cost of land may make the precast business economically non-viable. It may also become a big entry barrier for potential new precasters [7].

5. CONCLUSIONS AND RECOMMENDATIONS

Human resource problem has over the years, impeded the sound development of the construction industry of Singapore. The prefabrication technology appears to be the ideal way to resolve this problem and to improve the poor image of the construction industry. The local authority realizes its potential. With the mandatory requirement of the minimum buildable score the demand for prefabricated components will have a great surge. The challenge ahead lies on how the prefabrication industry in Singapore can meet this demand in a competitive and economic way. More efforts should be devoted to advancing the expertise and practice of the prefabrication industry such as more standardization of the prefabricated components, more production technology in the precast factory, etc. Efficient land usage is another important issue in the prefabrication industry due to Singapore's limited land resource. Lastly, more attention should be paid beyond prefabrication. The automation of the works of site erection and assembly of prefabricated components will make the construction process more industrialized as a whole. Innovations in this area are necessary, as prefabrication technology becomes more popular in Singapore.

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[1] CIDB is the previous designation of the current Building & Construction Authority (BCA) in Singapore.