

# IDENTIFICATION AND REDUCTION OF NON-VALUE ADDING ACTIVITIES IN THE PRECAST CONCRETE CONSTRUCTION PROJECTS IN SINGAPORE

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Prefabrication systems are believed to have the potential for better environmental performance and have been adopted by the construction industry to meet the challenges posed by global climate change. However, there remains many areas in the prefabrication systems that can be improved in order to reduce carbon emissions, such as site layout, work flow and inventory control. This research therefore aims to identify the non-value adding activities that can be eliminated to reduce carbon emissions in the precast concrete construction projects in Singapore. A weighted factor model comprising 30 contractors in the Singapore construction industry is adopted. Two stages in the precast concrete installation cycle are investigated using the weighted factor model, which are site layout management and delivery management. The results indicate that there are many non-value adding activities in the precast concrete installation cycle that contribute to an increase in the level of carbon emissions, such as large storage area and lack of just-in-time sourcing. The analysis provides good practice guidance and can be used as a checklist for contractors to achieve low-carbon installation. The results will also be useful for regulatory agencies to provide recommendations for the construction industry to reduce carbon emissions.

Keywords: carbon emissions, non-value adding activities, prefabrication, sustainability.

## INTRODUCTION

Climate change has emerged as one of the most pressing environmental issues in recent years (Building Research Establishment 2004). The most significant source is carbon emissions, which causes considerable threat to human development, including sea level rises, death of humans and loss of biodiversity (Intergovernmental Panel on Climate Change 2001). Industry and human activities, e.g. fossil fuels consumption,

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produce greenhouse gases (GHGs) which affected the composition of the atmosphere. It is believed that human activity is the most significant source of emissions, which is mainly caused by fossil fuel consumption, such as petrol, gas, oil and diesel.

The construction industry contributes to an increase in the level of carbon emissions in many ways (Kruse 2004). For example, the cement section alone accounts for 5% of global man-made carbon emissions (Worrell *et al.* 2001a). The manufacturing of raw materials (e.g., cement and steel) and chemicals have a considerable impact on carbon emissions (Worrell *et al.* 2001b). The transport of raw materials, such as cement, aggregates, and steel, is energy-intensive, particularly for countries like Singapore that heavily rely on the import of raw materials (Wu and Low 2011). The on-site construction of buildings is not always effect and may generate unnecessary carbon emissions (Wu and Low 2012). Precast concrete products are therefore advocated because of their potential benefits towards better environmental performance (e.g., Sanders and Phillipson 2003; Gorgolewski 2005; Tam *et al.* 2006). Many studies have been completed on the improvement that can be made for precast concrete manufacturers (Ballard *et al.* 2003; Ko 2010; Wu and Low 2011). However, it should be noted that the complete life cycle of precast concrete products should also include the installation, operation and demolition. This study therefore aims to take the first step to identify the non-value adding activities in the installation cycle of precast concrete products. The non-value adding activities in site layout management and supply chain management are firstly discussed in this paper.

## **NON-VALUE ADDING ACTIVITIES AND ENVIRONMENTAL PERFORMANCE**

Originating from the Toyota Production System (TPS), the lean concept is the observation that there are two aspects in all production systems: conversions and flows (Koskela 1992). Conversion activities refer to those which actually add value to the product or process. Flow activities refer to non-value adding activities. Only value adding activities are essential to the production process. It is a waste of time and resource to apply improvements to flow activities. The lean concept therefore aims to create an environment where conversion and flow activities are separated and treated differently. Conversion activities are improved while flow activities are eliminated at the same time. Some of the improvement technologies that originate from the lean concept include:

- Just-in-time (JIT): The right parts needed in production reach the assembly line at the time they are needed and only in the amount needed in a flow process (Ohno 1988).
- Total quality control (TQC): The concept refers to three extensions: expanding quality control from production to all departments; expanding quality control from workers to management; and expanding the notion of quality to cover all operations (Shingo 1988).
- Concurrent engineering: It refers to an improved design process characterized by rigorous upfront requirements analysis, incorporating the constraints of subsequent phases into the conceptual phase, and tightening of change control towards the end of design process (Koskela 1992).
- Employee involvement. The organizational goals and personal goals can both be achieved if employees are treated with equity and respect in terms of being involved with decision making, being provided with meaningful jobs and being given the opportunity to learn (Stendel and Desruelle 1992).

Elimination of non-value adding activities has proven to be effective in increasing environmental benefits. Luo *et al.* (2005) found that it could contribute to improve quality and supply chain. Nahmens (2009) found that by applying the concept to a production line, 9 to 6.5 people (labour waste), 12% space (equipment waste) and 10% wallboard (material waste) can be reduced. Miller *et al.* (2010) applied the concept to a small furniture production company and found that it can help the company meet every increasing customer demands while preserving valuable resources. In these studies, wastes, environmental burdens, and environmental deterioration were commonly used as the contributions that can be achieved by applying the concept.

## RESEARCH METHODOLOGY

A questionnaire was designed to identify the non-value adding activities in the site layout and delivery management practices. The questionnaire was divided into different sections to include all possible non-value adding activities. In site layout management, the categories of non-value adding activities included: 1.1) construction materials; 1.2) site facilities; 1.3) statutory requirements; 1.4) construction requirements; 1.5) temporary works and services; 1.6) storage area; and 1.7) managing the construction site. Similarly, in delivery management, the categories included: 2.1) damages during transportation; 2.2) selecting precasters; 2.3) just-in-time management; 2.4) other delivery management practices.

### Population, samples and sampling method

The questionnaire was distributed to all major contractors in Singapore. According to Building and Construction Authority (2010), the registered contractors in Singapore were classified into seven levels by their financial grade, which are A1, A2, B1, B2, C1, C2 and C3 (A1 being the highest financial grade and C3 being the lowest financial grade). According to the Directory of BCA Registered Contractors and Licensed Builders (Building and Construction Authority 2010), there were 87 contractors within the higher financial grade (A1 and A2), who would frequently be awarded with public housing projects in Singapore. These 87 contractors would therefore form the population of this study. In accordance with the data analysis method, which will be explained below, a minimum of 30 contractors was required in order to conduct the parametric tests to test the significance difference between different non-value adding activities. Convenience sampling method was used to choose the samples from the population. The contractors who were firstly interviewed were requested to provide one or two more contractors who had been involved in precast concrete projects in Singapore. 32 contractors were approached by email and telephone. Because of the complexity of the questionnaire, semistructured interviews were requested with either the site managers or the project managers. A total of 30 responses were received.

### Data analysis method

In order to identify the key non-value adding activities, a weighted scoring model was adopted in this research. According to Williams (1993), the risk concept could be broken into the two factors: probability of occurrence (P) and level of impacts (I). The severity of the risk (S) can therefore be described by multiplying the probability of occurrence with its corresponding impact, as shown in the following equation:

$$S = P \times I$$

A five-scale value range was adopted to assess the probability of occurrence of the non-value adding activities in the installation cycle. The range was: (1) very low; (2)

low; (3) medium; (4) high; and (5) very high. Accordingly, the impact on carbon emissions was assessment by a five-scale value range, which was: (1) insignificant; (2) minor; (3) moderate; (4) major; and (5) catastrophic. Paired sample t test was used to test the significance between two different non-value adding activities at a 95% confidence interval. The null hypothesis was that the difference between the two mean values was zero. If the  $p$  value was less than 0.05, the null hypothesis would be rejected. In other words, the two non-value adding activities compared in the paired sample were significantly different.

## SITE LAYOUT MANAGEMENT

According to the results of the survey, as shown in Table 1, the most frequent non-value adding activities in the construction sites where the precast concrete products were used included:

- 1.7.3 Site layout plan is not placed on the notice board for information (2.63)
- 1.1.3 Does not think of the green building materials (2.53)
- 1.7.4 Changes to the site layout plan are not notified immediately (2.47)

The decision regarding the use of green building materials should be made before transportation and installation. Because of its high priority, the use of green building materials was discussed in site layout management. The site layout plan was very important when there are changes in project managers, supervisors and subcontractors during the contract. According to the contractors, green building materials were only used in projects that were targeted for green mark certification. The most commonly used green building materials was the green concrete which was specially manufactured using fly ash or other recycled materials to replace Portland cement. Although the price of such green concrete was slightly higher (S\$5 higher per cubic metre for the grade G35 concrete) than the Portland cement concrete, it was seldom used in precast concrete projects unless the projects were targeted for green mark certification. In addition, in precast concrete projects where the green concrete was used, only the minimum requirements in the green mark certification programmes were met. It seems that more incentive schemes from the government should be promoted to encourage the use of more green building materials.

One significant difference between the precast concrete factories and the construction sites was the storage area. Unlike in precast concrete factories where large storage area was provided (Wu and Low 2011), the storage area in the construction sites was relatively small. Contractors placed the order based on a quantity estimation in the following one or two days. However, it should be noted that non-value adding activities such as transferring and singling out activities happened regardless of the size of the storage area. Carbon emissions were emitted no matter which storage type was used.

In addition, the three most important factors that would increase the level of carbon emissions were:

- 1.1.3 Does not think of the green building materials (4.37)
- 1.7.1 Site layout plan is not tested for economic and efficient construction (3.80)
- 1.1.2 Inaccurate estimation of quantities required (3.77)

Contractors agreed that the green building materials were very important if they aimed to achieve low carbon construction. In addition, the site layout should be designed to

support economic and efficient construction, especially for transportation and erection activities which relied on the use of equipment and plants heavily. If a JIT delivery system was adopted in the construction sites, accurate estimation of the quantities of precast concrete products should be focused on. All contractors stated that the quantities could be accurately estimated based on a stable construction schedule.

When considering both the probability and impact, the severity of these non-value adding activities in site layout management is shown in Table 1.

The most important factors included:

- 1.1.3 Does not think of the green building materials (10.83)
- 1.7.1 Site layout plan is not tested for economic and efficient construction (6.93)
- 1.1.1 Improper specifications of the precast concrete products (6.93)
- 1.1.2 Inaccurate estimation of quantities required (6.73)

The contractors agreed on the importance of using green building materials to achieve low carbon construction, as well as the importance of an effective site layout plan to support green construction activities. The specifications of the precast concrete products should be completed at the very start and minimum alterations should be made to the specifications. According to one contractor, changes made from using off-site fabrications to on-site fabrications had happened in the past. Such changes would cause modifications to the site layout plan, as well as the erection method, causing more carbon emissions to be emitted. Five ranking groups were identified, as can be seen from Table 1. When allocating resources (time, human resources and costs) to eliminate the non-value adding activities, the ranking groups that were identified by the paired sample t-tests should be considered. For example, although factor 1.7.1 (Site layout is not tested on economic and efficient construction) had higher severity than factor 1.5.2 (Tower cranes' fully blocked area should be large), these two factors were statistically insignificantly different.

Table 1: Ranking and grouping of non-value adding activities in site layout management

Ranking	Factor No.	Description	Severity		
			AR	Sig. (2-tailed)	SD
1	1.1.3	Does not think of the green building materials	10.83	N/A	4.43
2	1.1.1	Improper specifications of the precast concrete products	6.93	0.0001 N/A	3.19
2	1.7.1	Site layout plan is not tested for economic and efficient construction	6.93	1.000	3.15
2	1.1.2	Inaccurate estimation of quantities required	6.73	0.709	2.68
2	1.5.3	Inappropriate design of sitting of static plants	6.10	0.232	1.56
2	1.5.4	Inappropriate design of parking of mobile plants	5.90	0.177	1.86
2	1.5.2	Inappropriate design of tower cranes' fully blocked area should be large	5.63	0.064	1.65
3	1.7.3	Site layout plan is not placed on the notice board for information	5.03	0.010 N/A	2.24
3	1.5.1	Inappropriate design of space for access	4.87	0.672	1.94
3	1.3	Does not comply with mandatory statutory requirements	4.77	0.676	2.49
3	1.7.4	Changes to the site layout plan are not notified immediately	4.67	0.317	2.38
3	1.4.4	Does not pay full attention to the use of other equipment and plants	4.60	0.489	2.46
3	1.2	No overall consideration of construction site facilities	4.27	0.156	1.64
3	1.7.2	Site layout plan is not sent to subcontractors and general foreman	4.23	0.056	2.30
4	1.4.2	Does not pay full attention to the office space	3.60	0.011 N/A	1.28
4	1.4.5	Does not pay full attention to services required	3.60	0.9999	1.40
4	1.6.3	Over provide storage area – Open store	3.5	0.748	1.28
4	1.4.3	Does not pay full attention to the maximum number of men on site	3.37	0.243	1.47
4	1.6.2	Over provide storage area – Weatherproof store	3.23	0.239	1.36
4	1.6.1	Over provide storage area – Secure store	3.17	0.146	1.26
5	1.4.1	Does not pay full attention to the duration	3.10	0.037	1.18

Notes: AR = Average Rating; SD = Standard Deviation

## **DELIVERY MANAGEMENT**

Similar to the section on site layout management, the non-value adding activities in delivery management were rated by both probability and impact using a five-point scale. The most frequently occurring non-value adding activities in delivery management were:

- 2.2.3 Transportation is not taken into consideration (3.17)
- 2.3.3 No advance order and confirmation order (2.80)

22 contractors (73.33%) stated that transportation was not always a consideration when selecting the precasters (when P=5, P=4 and P=3). The delivery performance of the precasters was very good in the aspects of managing to deliver on time with the right quantity and good quality, as rated by the 22 contractors. It was sometimes the contractors' fault that the delivery vehicles were left idling due to site congestion. The two-order system derived from the JIT delivery system and as proposed by Tommelein and Li (1999) was sometimes not adopted by contractors who believed that one order would be good enough because of the small quantity ordered every time.

However, it should be noted that the two-order system would also help the precasters to deal with changes. It was not only the contractor who could benefit from this system. On the other hand, a few factors which did not frequently happen in delivery management included:

- 2.3.4 Insufficient data exchange with the precasters (1.50)
- 2.3.1 Demand fluctuations (1.60)
- 2.4.1 No accurate delivery notes (1.67)

The data exchange between the precasters and the contractors seemed to be sufficient. The contractors were not facing demand fluctuations. Although the daily amount of usage might vary, such variation was very minimal. However, it was surprising to note that no immediate use of the delivered precast concrete products was conducted based on the stable erection schedule.

The most important factors that could cause an increase in the level of carbon emissions during transportation included:

- 2.4.2 Insufficient care (3.87)
- 2.1.2 The driver is not aware of a few typical damages during transportation (3.60)
- 2.4.3 Lack of routine inspection (3.57)

It seems that the contractors agreed on the important role played by the drivers during transportation. All contractors stated that by providing sufficient care, the damages from transportation could be reduced. Routine inspection before the release of the precast concrete products was very important to reduce carbon emissions from transportation. According to one contractor, during a three-month period, two rejections of the precast concrete products had happened, causing re-delivery to be arranged.

On the other hand, the large quantity supply base was not rated as an important factor by the contractors. Even if the quantity required for the next few days was delivered to the construction site, the precast concrete products could be stacked appropriately to

avoid damages. In addition, as the installation schedule was very stable, the contractors would not face any demand fluctuation. It is a common practice to order the precast concrete products to be used in the next one or two days. Consequently, large quantity supply would not happen in current construction projects which used the precast concrete products.

Table 2: Ranking and grouping and non-value adding activities in delivery management

Ranking	Factor No.	Description	Severity		
			AR	Sig. (2-tailed)	SD
1	2.4.2	Insufficient care	10.07	N/A	2.88
1	2.2.3	Transportation is not taken into consideration	9.20	0.183	2.61
2	2.1.3	Inappropriate packings and supports	8.70	0.0495 N/A	2.49
2	2.4.3	Lack of routine inspection	8.50	0.798	3.51
2	2.1.2	The driver is not aware of the few typical damages that may occur during transportation	8.30	0.498	2.63
2	2.1.1	No skilled attention to the details of supports and frames	8.20	0.471	2.75
2	2.3.3	No advance order and confirmation order	7.57	0.199	3.76
2	2.2.2	No single sourcing supply with long-term contract	7.40	0.142	3.79
3	2.3.2	Not fully prepared for the arrival of the precast concrete products	7.20	0.008 N/A	3.04
3	2.2.4	No quality audits of the precasters prior to the award of the contract	6.97	0.800	4.20
3	2.1.4	No standing instructions	6.43	0.220	2.36
4	2.3.1	Demand fluctuations	5.53	0.041 N/A	3.19
4	2.4.1	No accurate delivery notes	5.03	0.336	2.53
5	2.3.4	Insufficient data exchange with the precasters	4.37	0.021 N/A	2.30
5	2.2.1	Large quantity supply base	3.53	0.077	1.72
Notes: AR = Average Rating; SD = Standard Deviation					

The severity of the non-value adding activities is shown in Table 2. The most severe non-value adding activities included:

- 2.4.2 Insufficient care (10.07)
- 2.2.3 Transportation is not taken into consideration (9.20)
- 2.1.3 Inappropriate packings and supports (8.70)

In order to achieve low carbon transportation for the precast concrete products, it seems that contractors should take transportation into consideration by ordering

locally manufactured products. The price structure should not be the only consideration especially under the “all-in-one” price structure. For one contractor, there were three L6 (highest financial grade) precasters located 3km away from the project site and yet the contractor chose one precaster that was located 15km away. The selection would cause more carbon emissions to be emitted during transportation. In addition, by providing appropriate and sufficient packings and supports as well as sufficient care, damages during transportation could be eliminated.

## DISCUSSIONS

Some of the practices originated from the lean concept, e.g. the JIT delivery, were challenged by some academics. For example, Rothenberg *et al.* (2001) stated that the survey results did not significantly support the hypothesis that lean is greener, and it was only interview data that supported the relationship between lean management and environmental management practices.

As to JIT delivery, many academics argued that the small lot nature of just-in-time would actually increase the carbon emissions level in the transportation cycle. Venkat and Wakeland (2006) stated that just-in-time supply chain did not necessarily reduce carbon emissions. When cold storage is not required for a particular product line, emissions depend largely on the transportation mode, and larger deliveries at less frequent intervals all along the supply chain generally lead to the lowest emissions. Some project managers interviewed have raised the same concern.

However, it should be noted that the JIT delivery system has several pillars, including at least:

- Just-in-time (JIT): JIT means that the right parts needed in production reach the assembly line at the time they are needed and only in the amount needed in a flow process (Ohno 1988). The just-in-time nature was believed to have benefits in reducing carbon emissions, as observed by Wu and Low (2011). The immediate use of building materials after arrival can significantly reduce transferring and singling out activities, thus reducing carbon emissions (Wu and Low 2011).
- Small lot sizes: Small lot sizes were considered as an important feature of JIT sourcing and were believed flexible enough to overcome the obstacles of higher delivery costs and loss of discount rates (Banerjee and Kim 1995). The small lot nature of JIT delivery can possibly increase the carbon emissions. However, the amount of carbon emissions should be assessed case by case before conclusions can be made. The small lot nature of JIT delivery can reduce the inventory level. The benefits achieved by lower inventory level, e.g. lower carbon emissions in this case, should also be assessed.
- Long-term relationship: A long-term relationship between contractors, subcontractors and suppliers is essential to a JIT delivery system. It can help improve the information exchange between contractors, subcontractors and suppliers, thus supporting the JIT nature as discussed earlier.

It is therefore necessary for contractors to balance the three pillars of JIT delivery. Starting with just-in-time and long-term relationship can help the contractors achieve some benefits in reducing carbon emissions.

## CONCLUSIONS

In accordance with previous literature, this paper has identified many areas in the installation cycle of precast concrete products that can be improved. These non-value adding activities were described, evaluated and ranked by a weighted factor model. Two value stages, which are site layout and delivery, were investigated. It is found that site layout design, the use of green materials, accurate specifications of precast concrete products and estimation of quantities are the factors that can bring down the carbon emissions level. Similarly, in delivery management, it is believed that by providing sufficient care and support system to the precast concrete products, as well as arranging the delivery in a just-in-time manner, the carbon emissions can be reduced. Knowing the sources of unnecessary carbon emissions, appropriate actions can therefore be taken for further improvement.

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