Factors Influencing Productivity of Concreting Equipment in Indian Construction Projects

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Abstract
Equipment productivity plays a significant role in the sustainability of any construction organisation in this stiff competitive market. In developing countries, one of the main concerns on construction sites is low productivity of concreting equipment. Concreting equipment form the core equipment in most of the construction projects and the costs associated with the use of these equipment are usually high. As a result, low productivity of concreting equipment affects both schedule and cost. The purpose of this paper is to identify various factors that affect productivity of concreting equipment in construction projects, especially in developing countries such as India. A questionnaire survey was conducted among experienced professionals (managers and site engineers) from across the Indian construction industry. The study identified five key factors as: (1) *improper maintenance; (2) unskilled operator; (3) poor planning; (4) inefficient operator;* and *(5) lack of coordination among different crews.* The major findings also indicate that engineers and managers share a general perception of the factors affecting equipment productivity; however, differences do exist. The outcome of this paper will help in addressing the issue of low productivity of concreting equipment in construction projects.

Keywords
Concreting; productivity; construction equipment; Indian construction industry.

1. Introduction

The construction industry makes significant contribution to both economy and employment in both developed and developing countries (Arditi and Mochtar 2000, Deloitte 2014). Despite its high significance, many construction projects suffer from time delays and cost overrun (Sun and Meng, 2009). Iyer and Jha (2006) reported that 40% of 646 national projects in the Indian construction industry were approximately 40% behind schedule. Whereas, Ahsan and Gunawan (2010) compared the performance of international development projects in India, China, Bangladesh, and Thailand, and found that construction projects in India had the worst schedule performance. In a study by KPMG International (2013), 77% of the total executives interviewed from 165 engineering and construction companies around the world identified delays among the topmost reasons behind underperformance in construction projects.

In today's global economic conditions, improving productivity in the construction projects could eliminate time and cost overruns. It has become a key focus area over the last decade attributable to its strong potential in benefitting the construction industry. However, in a construction project, a large number of factors affect productivity and that there is a necessity to locate the most influential ones among them. In the developing construction markets such as India, low equipment productivity has remained one of the leading causes of delay in the completion of construction projects.

As per the data provided by statistics portal *Statista*, the consumption of cement and aggregates in India has gone up to 255 million metric tonnes and 1.7 billion metric tonnes respectively in the year 2015. These figures indicate the amount of concrete being used in developing nations due to the rapid pace of construction and infrastructure development. Although, a large number of researchers have provided their insights into the identification of factors affecting labour productivity (Hughes and Thorpe, 2014; Naoum, 2016), reasons behind low productivity of concreting equipment have not been explored in sufficient depth.

2. Literature Review

In comparison to studies related to labour-intensive projects, research on workflow management and factors that cause disruptions in equipment-intensive operations has not been as undertaken extensively (Choi and Minchin, 2006). Yi and Chan (2014) concluded that hourly output is the most reliable measurement of productivity for construction activities. This definition of equipment productivity also reveals that when the productivity rate decreases, the activity duration increases. When the duration increases, it will result in higher fuel consumption and higher emissions and thereby, damaging the environment (Hajji, 2015). Consequently, poor equipment productivity has also negative implications for the environment, in addition to cost and schedule overruns.

The researchers have identified issues such as old and obsolete construction equipment, insufficient number of tools, shortage of spare parts, improper service and maintenance, slack use of machinery, unavailability of consumables, poor equipment maintenance, slow equipment repairs, improperly maintenance of power tools, and inefficient operator as the most significant causes associated with construction equipment that lead to poor productivity in construction projects (Dai *et al*., 2007; Rivas *et al.,* 2011). Regarding equipment productivity in concreting operations, factors such as such as placing method, organisation and management, labour crew skills, pumping spaces, site congestion, and number of truck mixers available have been found significant (Anson and Wang, 1998; Zayed and Halpin, 2001).

Alwi (2003) found that logistic problems and site congestion were the two major causes associated with low equipment productivity in Indonesia. Moreover, operator's skill and training were also found to be among the key factors that negatively affect equipment productivity. Zayed and Nosair (2004) identified factors that cause a delay in the concreting operation and their effect on concreting equipment productivity and overall cost. The major factors affecting uncontrolled delays were availability of work front, job specifications, and weather conditions. Whereas, controlled delay factors included management conditions, skill of pouring crew, number of truck mixers, site conditions, and material supply system. Prasertrungruang and Hadikusumo (2009) studied efficient management and downtime consequences of equipment used in highway construction by taking into consideration factors like operational practice, maintenance management, equipment life, and training of equipment operators. The researchers found that variables affecting equipment productivity include machine availability rate, relationship among dealers and contractors, and equipment administration policies. The main reason for this research study is a perceived gap in the current body of knowledge in relation to concreting equipment productivity, especially in the context of developing countries such as India.

3. Research Method

The literature review helped in the identification of factors that affect the productivity of concreting equipment. In addition to the literature review, five pilot interviews with the project managers who had more than 16 years of experience, were also conducted to gain more insights into factors affecting productivity of concreting equipment. Finally, on the basis of literature review and subsequent discussion with the experts, a total of twenty-nine factors influencing the productivity of concreting equipment were identified in the context of the Indian construction industry. These factors were then structured into a questionnaire in two stages: first, a preliminary questionnaire was developed and pre-tested by a small group of four project managers to ensure that the questions were easily understood and correctly interpreted by the members of the population. Then, after a few amendments in the design of the questionnaire, a final questionnaire was developed for collecting responses from the construction management professionals working across the country.

For collecting the data, it was considered important to select the construction sites appropriately. Therefore, to develop a current and more generic understanding of the factors affecting concreting equipment, only those under-construction projects which had a project cost of more than $10 million, were selected for this research. Moreover, to find out the common issues at the level of the industry and to minimise the bias in response, only one random project from a contractor was included while dropping out the other projects involving the same contractor. As a result, 11 construction projects out of 26 initially selected projects from the national capital region (NCR) and two adjoining states of India qualified for this research. These projects included: three housing projects, six power plant construction projects, and the remaining two were industrial projects. To receive the views from cross-organisations, responses were collected from both managers and site engineers.

A total of 130 questionnaire sets were initially distributed both by hard copy and via email. After four months of regular follow-up, 91 respondents returned the questionnaires, of which 82 were duly completed and therefore, formed the basis of this paper. The respondents included 39 managers and 43 site engineers. The response rate percentage was 63.1%, which is well accepted. Of these, 32 respondents were working on industrial projects whereas; balance 50 respondents were from building and infrastructure projects. The respondents' mean experience was 16 (standard deviation 8 years). Because of the high experience, the respondents can be considered suitable to answer the questionnaire. According to Vaus (2001), in the smaller size of samples, the quality of the responses would be considered to be highly reliable for the analysis if the respondents have relevant industry experiences and clear understanding of the questionnaires. Initially obtained in terms of a five-point Likert scale in which 1 represents strong disagreement and 5 represents strong agreement, responses were stored and analysed using the *Statistical Package for Social Sciences (SPSS)* software program. In order to determine the relative rank of each factor surveyed, the data collected were analysed using the Relative Importance Index (RII) technique (Fugar and Agyakwah-Baah, 2010). Before calculating RII for each factor, it was deemed necessary to test the reliability of the scale used. Hence, Cronbach's alpha coefficient (α) was calculated for the data set to determine the internal consistency and item correlation. Generally, a questionnaire with α-value of 0.7 is considered reliable (Field, 2009). The value of alpha was calculated to be 0.814, which is acceptable.

Each of the factors affecting the productivity was ranked on the basis of RII using the following formula:

$$\sum wA \text{ X } N \qquad (1)$$

where, *w* = weight assigned to each factor by the respondents and it ranges from 1 to 5; *A* is the highest weight (i.e., 5 in this case); and *N* = total number of respondents. The highest RII value indicates the most critical factor with rank 1, the next most critical factor with rank 2 and so on. The overall ranking was based on the total number of responses (including managers and site engineers).

Furthermore, a two-sample t-test was conducted among the means of responses of the two groups for each individual factor at significance level: $\alpha=0.05$ using SPSS to measure any significant differences among the respondents' perceptions.

The null hypothesis H_0 and alternate hypothesis H_1 considered in the analysis are given below:

H_0: There is no significant difference between the group means of two samples (i.e. $\mu_1 = \mu_2$).
H_1: There is a significant difference between the group means of two samples (i.e. $\mu_1 \neq \mu_2$).

If the p-value is less than 0.05, it means that the difference between the means of different groups is statistically significant and therefore, the null hypothesis is rejected.

After ranking all the factors on the basis of mean values, Spearman rank correlation was used to evaluate the strength of a relationship between two sets of data (Field, 2009). The nearer the value of R_s is to either +1 or -1 the stronger it is likely to be the mathematical correlation between the data sets and the more likely it is that the result is significant if there is, in fact, a relationship between the two variables correlated. The Spearman correlation rank coefficient test was performed to examine the hypothesis that there is no significant difference between the rankings of factors by the managers and site engineers. As suggested by Nolan (1994), the calculated values of Spearman's coefficient were compared with the critical value at 95% level. The Spearman's rank correlation coefficient was calculated using the following equation:

$$R_s = 1-6\sum d2n(n2-1) \quad (2)$$

where n = number of pairs ranked and d = difference between corresponding ranks.

4. Analysis and Results

Using the RII values, the rank orders of different factors were obtained for all categories of responses: all responses, and separately for those of managers and site engineers. The results are presented in Table 1. The highest-ranking factors observed in all responses category have been discussed in more detail in the following sections.

Table 1: RII Values, Rankings, and t-Test Results of Various Factors Affecting Concreting Equipment Productivity

Factors	Overall		Manager		Site Engineer		t-test results at significance level 0.05	
	RII	Rank	RII	Rank	RII	Rank	F	p-value
Improper maintenance	0.915	1	0.954	1	0.879	2	10.083	0.002
Unskilled operator	0.868	2	0.887	3	0.851	6	9.560	0.003
Poor planning	0.866	3	0.944	2	0.795	14	241.639	0.000
Inefficient operator	0.861	4	0.846	5	0.874	3	7.736	0.007
Lack of coordination among different crews	0.856	5	0.841	6	0.870	4	8.662	0.004
Lack of materials	0.839	6	0.754	15	0.916	1	543.374	0.000

Wrong selection of equipment	0.834	7	0.836	7	0.833	9	1.120	0.293*
Location of batching plant	0.829	8	0.831	8	0.828	10	2.034	0.158*
Non-availability of spare parts	0.824	9	0.800	11	0.847	7	0.822	0.367*
Non-availability of work front	0.820	10	0.795	12	0.842	8	0.210	0.648*
Inexperienced equipment manager	0.815	11	0.821	9	0.809	13	12.028	0.001
Incompetent execution team	0.805	12	0.867	4	0.749	26	9.631	0.003
Bad relationship with the subcontractor	0.790	13	0.790	13	0.791	15	1.670	0.200*
Frequent downtime	0.785	14	0.810	10	0.763	12	13.818	0.000
Unskilled labour	0.780	15	0.733	16	0.823	13	14.162	0.000
Batching plant installation	0.776	16	0.779	14	0.772	18	0.003	0.955*
Discontinuity in operation	0.768	17	0.713	20	0.819	16	7.915	0.006
Wrong placing techniques	0.761	18	0.728	17	0.791	16	17.038	0.000
Incompetent supervisor	0.756	19	0.723	18	0.786	18	26.196	0.000
Bad weather	0.751	20	0.708	21	0.791	17	60.017	0.000
Location of pour	0.744	21	0.621	26	0.856	20	1.102	0.297*
Bad condition of hauling road	0.734	22	0.687	22	0.777	24	31.434	0.000
Traffic congestion	0.729	23	0.667	23	0.786	19	32.687	0.000
Ownership-Owned/Hired	0.720	24	0.646	25	0.786	20	20.375	0.000
Organization structure	0.695	25	0.718	19	0.674	29	0.612	0.436*
Logistic issues	0.690	26	0.610	27	0.763	24	7.019	0.010
Non-compliance of safety standards	0.685	27	0.656	24	0.712	27	7.750	0.007
Lack of training and motivation	0.680	28	0.600	28	0.753	25	1.717	0.194*
Lack of productivity awareness	0.629	29	0.554	29	0.698	28	0.298	0.586*

**The mean difference is significant at the 0.05 level.*

Improper maintenance was ranked as the most crucial factor affecting productivity of concreting equipment. Since concreting equipment are subjected to harsh working conditions, the slurry and aggregates tend to wear away piston rings and other components. However, in developing countries, equipment is usually engaged throughout various shifts and even on weekends and holidays due to tight project schedule and seven days a week operating conditions on many construction sites. As a result, the equipment maintenance team usually does not get sufficient time to carry out necessary maintenance tasks. Downtime resulting from machine breakdown during operations has a substantial impact on equipment productivity and organizational performance as a whole (Schaufelberger, 1999). In addition to this, the cost of doing the repair in an unplanned manner in the middle of a job is expensive (Kannan, 2011). Implementation of preventive maintenance has been highly recommended by the previous studies to reduce the overall maintenance cost (Makulsawatudom *et al.*, 2001; Alinaitwe *et al.*, 2007). Thomas and Sudhakumar (2013) also concluded that quick repair of faulty equipment is essential to avoid productivity losses.

Unskilled operator was identified as the second most important factor. With the advent of hydraulics and equipment technology, various equipment such as concrete pump, boom truck, and batching plant have evolved with precise control units. Therefore, skilled and well-trained operators are needed for their efficient operation and control. However, most of the construction firms in developing countries perceive training and development as a costly and unnecessary affair. As can be seen from Table 1, the lack of training has received a lower ranking by the respondents. Due to the rapid pace of development, shortage of skilled operator has become a major issue in many construction projects. The problem of skill shortage in the construction industry has been stressed by various researchers who uphold that management should help in skill development to achieve productivity enhancement (El-Gohary and Aziz, 2013; Jarkas, 2015). Allmon *et al.* (2000) argued that an increase in the construction real wages may resolve the issue of skill shortage.

The factor *lack of proper planning* was ranked third with RII = 0.868. Good planning is the backbone of any activity and concreting is no exception. Due to improper planning, concreting equipment is either under- or over-utilised. Alwi (2003) found that improper planning around equipment use incurs large overhead expenses. Non-availability of the work front also severely affects the productivity of concreting equipment. Since productivity of the concreting equipment depends on the continuity of the operation, frequent stoppages in operation due to factors such as unavailability of labour, resources, work front, as a result of poor planning lead to underutilization of equipment. Choudhry (2015) found that an open and spacious work environment also increases the productivity to a certain extent. Moreover, the negative impacts of adverse weather on concreting equipment productivity could be reduced with the help of careful planning based on weather forecast.

Inefficient operator was placed at the fourth position by the respondents. In many countries, the construction sites generally operate in a dual shift of duration of 12 hours each due to a tight schedule. It was found that on many sites, sufficient number of operators were not employed by the contractor in order to reduce the overall cost. Enshassi *et al.* (2007) found that working seven days per week without any off day among the top ten factors negatively affecting construction productivity. A proper design of a work/rest schedule is an effective means of improving a worker's comfort, health, and productivity (Yi and Chan, 2014). Working overtime also causes physical fatigue to operatives, decreases their agility, stamina and motor skills, leading to low productivity and de-motivation (Jarkas *et al.*, 2012). As a result, even a very competent operator can be demotivated due to various site related issues (Naskoudakis and Petroutsatou, 2016).

Lack of coordination among different crews was also perceived by the respondents as an important factor causing low concreting equipment productivity. In India, labour workforce comes from various parts of the country and therefore, cultural differences in terms of working style and language affect the level of co-ordination. Concreting is a cyclic process which includes several tasks such as batching, transportation, placement, compaction and return to the batching plant. Consequently, starting from the arrangement of the pipeline to fixing formwork and reinforcement, and finally placement and compaction of the concrete, all of these activities are interconnected, however, usually performed by different crews. Therefore, proper coordination is essential in order to ensure an efficient and uninterrupted operation of concreting equipment.

As can be seen from two sample t-test results presented in Table 1, out of 29 factors, statistically significant differences between mean values of 10 factors were observed while in the remaining 19 factors, no difference in mean values of different respondents group was found. For example, for the factors wrong selection of equipment, the p-value for engineer-manager is 0.293, showing a statistically significant difference in the mean values of the managers and site engineers. These differences are due to the difference in the perception of various categories of respondents on the relative importance of some of the factors. While factors such as equipment selection and location of batching plant that come under the purview of management were relatively high ranked by the managers, factors related to site job conditions such as non-availability of work front, non-availability of spare parts, and location of pour received higher preference by the site engineers. However, by looking at the high mean scores of each of the factor, it becomes evident that each of the stakeholders is in general agreement on the importance of each of these factors. Furthermore, the Spearman's rank correlation coefficient was calculated as 0.711 for manager-site engineers using equation (2). The values of R_s correlation coefficient was found to be greater than the critical value at the 95% level. Therefore, it can be concluded that the perceptions of managers and site engineers showed a strong positive correlation and there was ample agreement on the overall ranking of the factors between these two groups.

5. Conclusion and Recommendations

This paper's intention has been to make an empirical contribution and it is noteworthy that the findings add to the existing literature on productivity of concreting equipment, by looking at the specific issues causing low productivity. The findings of the study indicated that the main factors responsible for the low productivity of concreting equipment are related to equipment management and workers' skills. Moreover, the managers and site engineers were found to agree statistically on the relative importance ranking of factors affecting productivity of concreting equipment.

In developing countries, low focus on workforce training and skill development coupled with the rapid pace of development has caused an acute shortage of skilled workforce. In addition to this, organisations the low wages paid by the organisations negatively affects workers' efficiency and motivation. The answer to the skilled workforce shortage lies in providing better training opportunities and more attractive employment incentives. The incidents of equipment breakdown could be reduced by developing and following a proper maintenance schedule for the concreting equipment. The implementation of preventive maintenance has been highly recommended by the previous studies. Moreover, the availability of resources and work front through proper planning and coordination are crucial for the continuous operation of concrete equipment.

The factors identified through this research would help the site management in devising new methods to address these productivity issues. The potential implications of this study are relevant to the challenges facing both private and publicly funded construction projects regarding delays and cost overrun. It is the authors' hope that the insights provided by this study will be used by the contractors to improve the productivity of concreting equipment. Like many of the research works, this study also has few limitations. Further research is required to examine the impact of these factors on concreting equipment productivity in more detail. Moreover, two sample t-test results presented the statistically significant differences in the mean values of various factors. Future work may be undertaken to identify the exact causes of difference in the opinion of different groups of respondents.

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