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Contractor Capacity and Waste Generation: An Empirical Investigation

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Abstract: This paper aims to test the hypothesis that an inverse relationship exists between the capacity of a contractor and the amount of waste generated in a construction site. In Sri Lanka, contractors are graded by an independent government agency and this study uses 15 projects undertaken by grade M1 to M5 contractors. M1 contractors constitute the highest grade and they have higher technical, financial and managerial capabilities. These projects are examined to determine cement wastages and link them to these respective grades to clarify their relationship. The major finding is that upper grade contractors, who are more capable, generate less waste compared to their lower grade counterparts. This suggests that contractor capacity not only has desirable outcomes for better time, cost and quality objectives but also benefits the environmental objectives of their clients. While the present grading system in Sri Lanka does not consider waste management, it is suggested that the waste management practices of contractors could vary immensely from the M1 grade to the lower grades. Consequently, future revisions in the grading system should seriously consider incorporating waste management practices to provide an incentive to contractors who appropriately manage their waste. In theory, this will encourage efficient waste reduction practices in construction sites.

Keywords: Construction waste, Contractor capacity, Waste reduction, Sri Lanka

INTRODUCTION

The construction industry is a very large consumer of natural resources (Treloar et al., 2003). While some materials require only simple processing, others are prone to complex manufacturing processes. Construction is identified as a large consumer of energy-intensive manufactured materials such as iron, steel, copper, glass, synthetic materials and cement. Therefore, the activities connected with construction have long-term effects on the natural environment (Kralj, 2011).

Unfortunately, this large portion of materials is not utilised efficiently by the industry and construction waste is regarded as a prime contributor to the total waste stream (De Silva and Vithana, 2008). The majority of materials come from non-renewable sources, so material waste has been identified as the most critical waste compared to labour and machinery waste (Ekanayake and Ofori, 2000); it creates economic, environmental and health problems (Yahya and Boussabaine, 2006).

The cost of waste materials is greater than their value because of added handling, transporting and tipping costs (Poon, 2007; Esin and Cosgun, 2007). Teo and Loosemore (2001) estimated that wasteful companies are at a 10% disadvantage in tendering for new work. Waste is also an expense to the wider society in the form of higher prices paid by clients (Faniran and Caban, 2007). Not

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only is it expensive to handle heavy and bulky construction waste, but valuable land is also set aside for such waste disposal. Resource depletion and environmental harm are other issues associated with waste.

The waste levels in the construction industry need to be reduced for environmental and economic reasons and it has become a sensitive topic among professionals in the construction industry (Yuan and Shen, 2011; Tam, 2008; Begum et al., 2006). To control construction waste, the first step is to identify its sources. Chen et al. (2002) proposed advanced waste auditing systems as a precursor for its effective management. Detailed knowledge of the incidence of waste and its causes is essential to understand the problem and find ways to prevent it. According to Teo and Loosemore (2001), even within the construction industry, businesses are not identical and it is likely that waste management initiatives and activities vary from company to company. In Sri Lanka, contractors with similar characteristics are assigned a grade at their time of registration by an independent government agency, the Institute for Construction Training and Development (ICTAD). It is likely that the waste management initiatives within a grade could be similar while between grades, they could be significantly different.

While many studies have examined different waste minimisation strategies and their impact on real-life construction settings, actual knowledge is limited regarding the influence of contractor capacity on waste generation. To fill this gap in the literature, this paper reports the results of a study on construction waste generation by different contractor grades. The aim is to explain the relationship between contractor capacity and the generation of construction waste. The study intends to guide the construction industry towards better waste reduction by identifying the impact of contractor capacity on construction waste generation.

CONSTRUCTION WASTE MINIMISATION

According to Hwang and Yeo (2011), the waste hierarchy provides an order of priority for managing waste, consisting of reduction, reuse, recycling, recovering and disposal. This hierarchy is based on the minimisation of resource consumption and environmental damage, which are important considerations in sustainable construction. Reduction is considered the most preferred way of managing waste by minimising waste generation. It requires the least resources and eliminates the burden of waste disposal and related costs. Additionally, waste minimisation can improve the public image of a builder (Poon, 2007) and it can lead to higher productivity, time savings and improved safety on work sites (Kulatunga et al., 2006).

Waste reduction is defined by Begum et al. (2007: 191) as "any activity that reduces or eliminates the generation of waste at the source usually within a process". Osmani, Glass and Price (2008) suggested waste minimisation through conscious design strategies. According to Begum et al. (2007), good operating, management and personnel practices are successful strategies for source reduction. Tam (2008) highlighted the importance of incentives for source reduction of waste. A reward scheme called the Stepwise Incentive System (SIS) produced 23% less waste when implemented in a case study project involving hotel redevelopment in Hong Kong. Kulathunga et al. (2006) and Teo and

Loosemore (2001) highlighted the importance of workers having a positive attitude towards minimising waste.

Jayamathan and Rameezdeen (2014) highlighted the use of direct labour in place of sub-contracted labour as a means of minimising waste, while Lingard, Graham and Smithers (2000) regarded proper workforce training as an effective method. Saunders and Wynn (2004) confirmed the above observations for sub-contractors, that awareness and understanding of waste minimisation is essential. Begum et al. (2007) concluded that the Malaysian construction industry does not favour training and incentive schemes regarding waste minimisation. Instead, buying good quality recyclable materials was more effective as a waste minimisation strategy. Dainty and Brooke (2004) tested a range of supply chain measures such as standardised designs, stock control, just-in-time delivery, supply chain alliances, dedicated specialist sub-contract packages and off-site fabrication and found them to be useful. De Silva and Vithana (2008) confirmed off-site fabrication generated less waste than on-site activities, while Yates (2013) preferred modular construction and standard sizes during the prefabrication process. According to Agamuthu (2008), strict government regulations and imposition of landfill levies have resulted in better construction and demolition waste management practices. While most developed countries have led the way in construction and demolition waste management, European nations in particular have been successful in reaping the benefits of anti-waste legislation.

GRADING SYSTEM OF CONSTRUCTION CONTRACTORS IN SRI LANKA

Construction contractors in Sri Lanka are mainly categorised into two types: general contractors and specialist contractors. General contractors are further categorised into seven fields and specialist contractors are categorised into three, as illustrated in Figure 1. Grading is completed to reduce the difficulties in selecting the appropriate group for relevant work and it ensures that a particular contractor can meet the required time, cost and quality targets of construction projects. The Institute of Construction Training and Development (ICTAD), an independent government agency whose mandate is to regulate the industry and build capacity to maintain a well-developed construction sector, administers the grading system.

The grading system is essentially linked to contractor registration that is also undertaken by the same agency. It should be noted that only those contractors registered with the ICTAD are eligible to tender for government projects. Contractors move up the ladder once they acquire the necessary capacity for a higher grade. The process ensures regular monitoring of capacity and continued governmental support. This support function is mainly handled by the Construction Guarantee Fund (CGF), a sister agency of the ICTAD (Abeysekara, 2005). The ICTAD (1995) defines grading as the screening of contactor capabilities to determine their ability to undertake different types and sizes of projects.

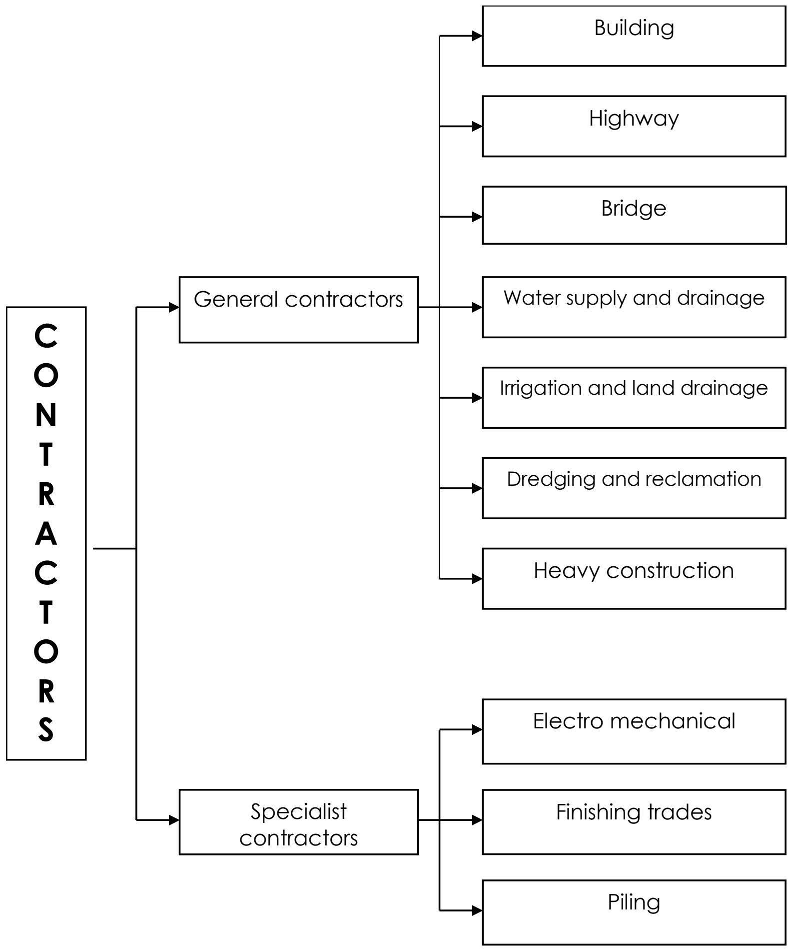

Figure 1. Categories of Contractors in Sri Lanka (ICTAD, 1995)

Grading also considers the financial, technical and managerial capabilities and merit and demerit points of contractors. Financial capability is assessed by their working capital and the availability of permanent overdraft facilities. Technical capability is evaluated by human resources (professionals and supervisory staff) capabilities as well as plant and equipment availability, while managerial capacity is determined based on previous experience and organisational strength (professionally qualified management staff). Merit points are awarded for the employment of trade-tested workers, professional engineers who are members of the Institution of Engineers Sri Lanka, operation of quality management systems and receipt of national construction excellence awards. Evaluation is completed based on a point system designed and implemented by the ICTAD. Once a grade is assigned, it is valid for three years and then requires renewal. Due to this comprehensive and systematic evaluation and monitoring, a contractor grade indicates the managerial, financial and technical capabilities of a contractor and is a measure of its capacity.

CONTRACTOR CAPACITY VS. CONSTRUCTION WASTE

According to Kofoworola and Gheewala (2009: 737), all efforts "must be directed at minimising construction waste generation by improving the managerial capacity of companies at the design, procurement and production stages". While design and procurement play a major role according to researchers (Osmani, Glass and Price, 2008; Jaques, 2000), Tam et al. (2007) claim that construction waste is mainly related to the workforce engaged in construction, including managers, supervisors and operatives. The more skills, knowledge and concerns for waste that workers have, the less waste is generated. Upper grade contractors typically have better skills and expertise compared to the lower grades, so the former are able to generate much less waste. This argument is further reinforced by Esin and Cosgun (2007) who state that all wastes are directly or indirectly caused by workers involved in a project due to sub-standard workmanship or insufficient training.

Lu et al. (2011) emphasise that the storage of materials on-site and their handling are the direct responsibility of site management and have a strong influence on waste control. Lu et al. (2011) further commented that negligence on the part of supervisory personnel could cause larger volumes of waste as workers try to complete an operation in the shortest possible time. Supervisory staff of upper grade contractors should be proactive and prevent these incidents from occurring. The causes of waste related to equipment shortages or poor or insufficient equipment choices can also be related to the capacity of a contractor. One study in Malaysia found that large-scale contractors had a strong positive attitude regarding waste minimisation compared to their medium- and small-scale counterparts (Begum et al., 2009). Attitude emerged as being related to the experience of these contractors. Attitude also is positive and stronger among educated employees and those who have participated in waste management training (Begum et al., 2009). Additionally, the benefits of waste management are higher when applied to larger projects (Hwang and Yeo, 2011).

The capacity of a contractor reflected through trained workers, plant and equipment ownership and managerial capability could be directly related to waste sources. Many researchers (Wang et al., 2010; Shen et al., 2004) highlight the role played by management in waste minimisation. However, there is limited empirical evidence linking contractor capacity to actual waste generation rates in construction sites. It is arguable that a relationship exists between contractor capacity and the rates of waste being generated. If this assumption is correct, upper grade contractors in Sri Lanka should be generating less waste compared to their lower grade counterparts. Thus, the study postulated the following hypothesis to be tested using empirical evidence.

> "Construction waste generation is inversely proportional to the capacity of a contractor."

RESEARCH METHODOLOGY

This study focuses on different grades of contractors in Sri Lanka and the building contractors who registered under the ICTAD were selected for the sample.

Although the ICTAD grading ranges from M1 to M10, contractors up to grade M5 were selected due to the lack of record keeping by lower grade contractors. Fifteen contractors, three from each grade, were selected for the study. Accordingly, fifteen case study projects handled by these contractors were used to quantify waste. The case study approach was employed because it allows waste to be quantified in the real-life context (Yin, 2003). Building projects (mainly commercial buildings except for a few institutional buildings) that ranged from SLR 100 to 300 million made up the sample. All projects were located within the Colombo metropolitan region and were procured using the traditional design-bid-build method. The projects were consciously selected from the same procurement method to avoid competitive bias. The study only examined cement waste because cement is a common material used for most construction projects in Sri Lanka. The scope was further narrowed to cement waste of concreting operations that used *in-situ* concrete.

Quantification of waste is normally conducted in two ways: work studies or material reconciliation. Gavilan and Bernold (1994) observed a serious limitation of work studies because the aggregation of waste arising from each stage is less than the total waste found from site records. Further, work studies are conducted while the work is on-going. Consequently, the actual amount of site waste is not documented due to several inherent disadvantages, including measurement difficulties, unaccountability of indirect waste and waste caused by other trades. Compared to work studies, material reconciliation is acceptable because similar studies have been successfully conducted using this method in other countries (Lu et al., 2011; Ekanayake and Ofori, 2000; Bossink and Brouwers, 1996). Material reconciliation measures the waste as the difference between store records and actual usage; this eliminates the above disadvantages. Consequently, the material reconciliation method was selected for quantifying the waste generation rates as given in Equations 1 and 2.

$$CW_{gi} = SR_{gi} - CU_{gi} \qquad \text{Eq. 1}$$

$$WGR_g = \frac{\sum_{i=1}^{n} \left(\frac{CW_{gi}}{CU_{gi}} \times 100 \right)}{n} \qquad \text{Eq. 2}$$

where,

CW_{gi} is the cement wastage (in kilograms) of the *g*th grade contractor for the *i*th case study project.

SR_{gi} is the store record of cement issued (in kilograms) for an identified activity of the *g*th grade contractor for the *i*th case study project.

CU_{gi} is the cement usage (in kilograms) of the identified activity calculated using the standard norms of the Building Schedule of Rates (BSR) based on bill of quantities of the *g*th grade contractor for the *i*th case study project.

WGR_g is the mean waste generation rate of the *g*th grade contractor.

Building Schedule of Rates (BSR) is a standard document published by the State Engineering Corporation (the former Public Works Department). It contains standard norms of material, labour and plant wastage for work activities that could be used for cost estimating purposes. These norms are revised regularly based on works studies undertaken by these organisations and ICTAD. Researchers gathered collections of store records and bills of quantities as well as calculated material waste. To avoid bias, the calculations were verified by project participants, including the storekeepers and project quantity surveyors who facilitated the data collection.

RESULTS AND DISCUSSION

Reconciliation results of store records with actual cement usage revealed that the mean waste generation rates (WGR_g of Equation 2 above) for M1 to M5 grade contractors were 5.35%, 6.01%, 5.97%, 13.35% and 24.18%, respectively. Figure 2 illustrates the mean waste generation rates for these five grades. Accordingly, the cement waste is considerably higher among lower grade contractors compared to those in the higher grades. This confirms the research hypothesis that "Construction waste generation is inversely proportional to the capacity of a contractor". Interestingly, the mean waste generation rates of grades M1 to M3 are very close compared to those of M4 and M5. The difference between the two groups is more than double. The mean waste generation rates of grades M1 to M3 combined (upper grade) is 5.78 compared to a mean waste generation rate of 18.76 for grades M4 and M5 combined (lower grade). An independent *t*-test was performed on the results for these two groups to verify the significance. The null and alternative hypothesis for the test is as follows:

$$H0: \mu_1 = \mu_2$$
$$H1: \mu_1 < \mu_2$$

where, μ_1 is the mean waste generation rate of the upper grade contractors and μ_2 is the mean waste generation rate of the lower grade contractors. With a 0.05 significance level, the independent t-test results indicated that the two groups had significantly different waste generation rates with a t value of –4.511 (p = 0.001).

Rameezdeen, Kulatunga and Amaratunga (2004) identified that the major proportion of cement waste could be categorised under "management" waste, which occurs due to the lack of supervision or management making wrong decisions such as uncontrolled delivery of materials to the site. Lack of skilled workers, poor distribution of labour and lack of supervision are the "people" related causes of waste, while poor planning and scheduling, poor decision-making and poor coordination are the "management" related causes. "People" and "management" related causes are the main reasons behind cement waste. Accordingly, it can be argued that the "people" and "management" aspects are better among higher-grade contractors, which leads to less cement wastage. This argument could be further established through the factors taken into consideration in grading the contractors in Sri Lanka. Accordingly, the human resources capabilities, organisational strength and managerial capability of the higher-grade contractors are superior to the lower grades, which in turn results in less construction waste.

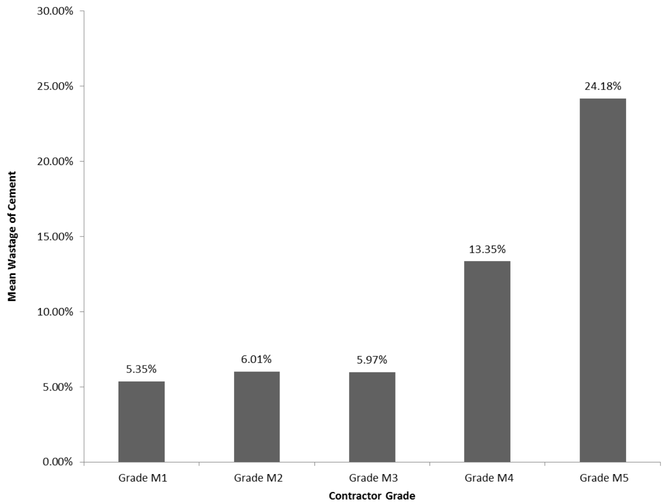

Figure 2. Wastage of Cement among Different Grades of Contractors

The findings of this research highlight the importance of the capacity of contractors to minimise construction site waste. The results suggest that selection of a higher-grade contractor will not only deliver better time, cost and quality objectives but also improve the environmental outcomes of a project. However, the existing literature does not recognise the importance of contractor capacity to maintain proper environmental conditions at a site including waste minimisation. Traditional contractor selection methods rarely involved environmental concerns (Watt, Kayis and Willey, 2010). Similarly, pre-qualification criteria are designed mainly to ascertain the financial, technical and managerial capabilities of a builder and not necessarily the environmental capabilities (Jaskowski, Biruk and Bucon, 2010). Thus, one of the implications of this study is the recognition of contractor capacity in dealing with waste and the possible recommendation for use in pre-qualification and contractor selection.

This study provides empirical evidence on the link between capacity and environmental performance of a contractor. However, in actual practice, contractor performance is evaluated using the traditional time, cost and quality outcomes of a project (Love and Holt, 2000; Kagioglou, Cooper and Aouad, 2001). Incentives and penalties are tied to these three performance indicators and environmental performance is rarely evaluated and rewarded. Researchers have shown that these three indicators alone are not sufficient to measure the true performance of a project (Chan, Scott and Chan, 2004). While environmental outcomes are slowly being embraced by the industry as a performance indicator, they are not widely used (Liu, Lau and Fellows, 2012; Vatalis, Manoliadis and Mavridis, 2012). As Terio et al. (2014) state, regulators, developers, contractors and clients are developing an increasing interest in environmental performance. Waste management has been identified as a relevant category to evaluate the environmental operation of a construction site. An important implication of this research is contractor capacity to deliver environmentally sustainable project outcomes and the need to reward such initiatives.

Similarly, ICTAD should recognise and assess the waste management strategies used by contractors when grading them. This would encourage contractors to develop and incorporate necessary waste management strategies in their operations. Thus, future revisions in the grading system should seriously consider incorporating waste management practices to provide an incentive to contractors who manage their waste appropriately. Additionally, this will provide indirect encouragement to reduce waste in construction sites. As highlighted by Hwang and Yeo (2011), implementing waste management as a company policy also allows companies to improve their public image and create a good impression on prospective clients.

CONCLUSIONS

This study investigated the relationship between contractor capacity and construction waste generation. The results indicate that cement waste gradually increases when contractor capacity falls from M1 to M5. This proves the hypothesis that "construction waste generation is inversely proportional to the capacity of a contractor". The study suggests that contractor capacity has an impact on the amount of waste generated in site operations.

The major contribution of this study is two-fold: the establishment of a relationship between construction waste and contractor capacity and guidance for the construction industry towards waste reduction by enhancing contractor capacity. However, it should be noted that the findings are based only on fifteen case studies from Grade M1 to M5 contractors and this is a major limitation of this research. Therefore, the degree to which the findings could be generalisable to all grades of contractors and to the entire Sri Lankan construction industry is contentious. Despite this limitation, the study exposes an important knowledge gap that requires further investigation of this relationship for other materials, other countries and different workplace settings. The study could be further extended to explore how different facets of capacity (technical, financial, managerial, etc.) contribute to minimising the problem of construction waste.

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