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Evaluating truck empty running in construction: a case study from Cape Town, South Africa

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ABSTRACT

The efficiency of any transport operation is dependent on the degree to which vehicle capacity is utilised on the forward and return trips. Efficiency requirements create the logistical challenges of finding backloads for returning vehicles. In the absence of backloads, vehicles travel empty on the return journey. Construction is fundamentally different from other freight services in that apart from requiring large quantities of material inputs, it also generates appreciable levels of waste. There is therefore, potential for reducing empty running by construction trucks through back-loading waste to points of disposal, reuse, recycling or reclamation. Back-loading, which is one of the reverse logistics processes is important for returning products that are damaged, obsolete or worn out and those unacceptable to buyers. Back-loading is also associated with utilising spare capacity in the supply chain to increase return on truck investment. This paper examines the operations and processes associated with construction materials and waste logistics and assesses the potential for reduction in truck empty running through utilisation of the reverse logistics concept.

Keywords: Construction, Reverse Logistics, Back-loading, Truck empty running

INTRODUCTION

The construction industry utilises millions of tonnes of materials and generates large quantities of waste. Moving these volumes of materials and waste requires large numbers of loaded vehicle transits. Therefore, transportation forms a large part of the construction logistics system (Bowersox *et al.* 2002).

Currently the logistics of construction materials delivery and waste removal are considered to be separate businesses. Consequently, the movement of construction materials from the point of production to the point of consumption is uncoordinated with that of waste removal from sites. The majority of construction materials suppliers have their own dedicated vehicles used to make deliveries to various customers' locations. The common practice is that adjacent construction sites do not synchronise their activities and contribute to congestion in the road transport system. Additionally, materials delivery traffic does not back-haul waste from sites to points of disposal. This results in an associated increase in vehicular traffic, as additional vehicles need to be made available to remove waste from sites. A consequence of this is that construction materials delivery vehicles, when travelling to or leaving a construction site, move full in one direction and empty in the opposite direction, respectively. The opposite is true for construction waste removal vehicles. There is therefore a significant opportunity to utilise the concept of reverse logistics to achieve process optimisation (Coyle *et al.*, 2003).

SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION

A significant amount of literature that has sought to highlight the role of Supply Chain Management (SCM) within construction has been developed over recent years. This has brought a valuable contribution to the revision of what should be seen as best practices in the industry. However, at present the bulk of SCM literature and practice is focussed on high level strategic issues, largely ignoring operational aspects related to logistics. This is a significant omission, given the fact that a recent study by the Building Research Establishment (BRE) in the UK indicates that as much as 30% of the cost of construction is attributed to transportation of materials.

The role of physical distribution is critical to the construction logistics process. It involves planning, organizing, coordinating and control of materials. It requires skilful design and control of data flows connected with products and production (Nilsson, 2006). An integrated supply chain strategy integrates production and associated processes and logistics functions in a seamless flow across the supply chain (Vogt *et al.*, 2002). Therefore, SCM goes beyond logistics. However the role of logistics is to satisfy the up-stream and down-stream parties in the supply chain (Rushton *et al.*, 2001; Butner *et al.*, 2005). Integrated SCM increases the importance of logistics activities and provides supply chain members with the opportunity to optimise logistical performance (Vrijhoef and Koskela, 2000; Gimenez, 2006). This represents a major departure from current logistics practices in the construction industry that are characterized by disparate efforts with limited or no coordination between organizations.

For instance, the method most commonly used to deliver materials to construction sites is that of dedicated, single use, for example, cement-carrying vehicles from a manufacturer to the point of consumption on site. Materials such as wooden frames, ready-mixed concrete, plasterboard and brick are also delivered in a similar way by dedicated vehicles.

REVERSE LOGISTICS

A lot has been written about the need to reduce either transport externalities or the number of vehicles on public roads (Banister *et al.*, 2000; Banister and Button, 1996; Vigar, 2002). In part, the reduction of construction waste in general, allied to increasing levels of on site recycling has helped efforts to reduce vehicle transits. There is also a growing interest within the construction industry in adopting reverse logistics systems as a means of underpinning efforts to recycle and manage waste more effectively (Marien, 1998). Reverse logistics may be applied to both the materials and waste management parts of the logistics chain and offer real environmental benefits (Kroon and Vrijens, 1995; Wu and Dunn, 1995; Carter and Ellram, 1998). According to Kroon and Virijens (1995), reverse logistics refers to the logistical management skills and activities involved in reducing, managing and disposing of waste from packaging and products. It includes reverse distribution, which causes goods and information to flow in the opposite direction from normal logistical activities (Wu and Dunn, 1995).

The most efficient reverse logistics solutions merge efficient forward and reverse flows into a single process of reducing, managing and disposing of waste (Kroon and Vrijens, 1995). Reverse logistics should start at the source of the materials, as the environmental impact of construction starts when the materials are first harvested for trees, or mined for metals, crushed stone, sand, gravel and gypsum. How they are extracted and how much is exploited can affect the surrounding environment, including the condition of soils, streams and forests. Processing, manufacturing and transportation of these products causes additional environmental impacts resulting from industrial pollution, burning of fuel and other processes employed (Rodrigue, 2003).

REVERSE LOGISTICS IN CONSTRUCTION WASTE MANAGEMENT

Construction and demolition (C&D) waste constitutes the waste generated during construction, renovation and demolition. C&D waste commonly includes building materials and products such as concrete, wood, glass, bricks, metals, roofing, insulation, door and window frames and flooring. Such a large and complex waste stream presents many opportunities for reducing waste and costs associated with construction activities. Reducing C&D waste can reduce overall project expenses by avoiding disposal costs and purchase of new materials and by generating revenue from sale of recycled materials (Wu and Dunn, 1995). To minimise environmental impact of construction, steps can be taken to re-use and recycle used materials and prevent waste. From incorporating used or environmentally preferable materials into construction or renovation to disassembling structures for re-use and recycling of their components each phase of the construction life cycle offers opportunities to reduce waste (Marien, 1998).

Within this evolving environment, a number of organisations are capitalising on reverse logistics systems combined with resource reduction processes to reduce the amount of waste fed into the supply chain and landfills (McKinnon and Ge, 2006). The reverse logistics process is often thought of as investment recovery as opposed to simply minimising the cost of waste management (Marien, 1998).

Another proactive strategy postulated by Marien (1998) is to reduce the amount of materials used in producing and delivering products. When a building comes to the end of its useful life, the amount of waste generated by its removal can be minimised through waste reduction techniques. Recycling the rubble results not only in savings but reduced truck traffic to and from site.

Notwithstanding, the above waste reduction efforts, there still are situations when construction waste needs to be removed from site. It is in such situations that utility of the reverse logistics concept could offer efficiency benefits to construction. To illustrate the concept of utilisation of spare capacity through reverse logistics, a case study was conducted on seven sites in Cape Town, South Africa.

DESCRIPTION OF THE CAPE TOWN CASE STUDY SITES

A sample of seven sites was purposefully chosen. The selected sites were logistically rather than statistically significant. The primary selection criteria were physical size of the development i.e. multi storey and use developments. The secondary consideration was that of construction technology i.e. reinforced concrete frame construction. A total of seven sites were selected for observation, all of which incorporated high-rise concrete-frame, mixed-use buildings though predominantly residential developments. This represented about 80 per cent of all such developments in the Cape Town Metropolitan Area.

RESEARCH METHOD

The research method adopted in the research reported in this paper envisaged the logistics system for construction materials and waste arisings from sites to consist of two main domains:

- the vehicular movements associated with delivery of materials to site; and
- the vehicular movements associated with the removal of waste from site to the point of either reclamation, recycling or disposal.

These domains may be described as subsystems within the overall project process and communication occurs within each subsystem. Each of these domains has its own dynamics of materials flows and communication patterns. This necessitated the use of a multi-case study format. More specifically, the reported research involved the analysis of seven case studies in Cape Town using a standard observation protocol. This entailed the examination of the volumetric loadings of building materials and waste arising transport in the city.

The data collected were used for the development of the conceptual simulation model. The objective was to identify the critical performance characteristics of the construction delivery and waste removal vehicle fleets. The expected result was an optimised model of the flow of construction materials and waste to and from site respectively.

RESEARCH DESCRIPTION

A two-phase pilot study was conducted during the observation period. The first phase was an exploratory study conducted on a large construction site in the Cape Town Central Business District. The main purpose of this investigative study was to identify the types and classifications of vehicles and their cubic and tonnage capacities, as well as the patterns of their movements. It involved both the observation of vehicle movements and talking to some drivers and site personnel about vehicular movements to and from site.

The results obtained were used in the design of a template to be used for data collection during the field study. In the second phase of the pilot study, the template was pre-tested on another large construction project in Cape Town to determine the practicality of using the instrument on site and the ease with which data could be captured. At this stage data capture problems such as the actual loading of vehicles were resolved by utilising visual identification of vehicle fill. Depending on a vehicle body type, fill was measured by deducting the area of the body length and height that was not taken up by the material being transported. The fill was either recorded as full, 75 per cent full, 50 per cent full, 25 per cent full or empty. The quarter scale was more appropriate as it made it easier for the researchers to obtain a higher and consistent accuracy.

In addition to providing a general feel of the patterns in vehicle movements to and from sites, the pilot study also assisted in identifying other parameters that had not been envisaged. Overall, the pretesting helped to modify the observation template and made it more effective in capturing data that would best answer the research questions and achieve the stated objectives.

RESEARCH RESULTS

Volumetric loading levels of vehicles on arrival and departure

The scarcity of relevant literature is indicative that currently, there is lack of an established understanding of the logistics of both materials delivery and waste removal in the construction industry. In order to address this gap in knowledge, data on volumetric loading levels of materials delivery and waste removal vehicles on arrival at and departure from sites was collected. Figure 1 shows 42% of vehicles arrived on sites full and 36% arrived empty.

This finding is significant for two reasons. Firstly, it generates a ratio for the first time in literature of the loading levels of vehicles going to sites. The ratio of 42%:36% approximates to almost 1.2 fully loaded vehicles to one (1) empty vehicle. Secondly Figure 1 supports the argument by McKinnon (1996) that there is a significant number of empty runs on public roads. This finding generates for the first time in literature an estimate of the proportion of construction vehicle empty runs. This proportion could be translated to be indicative of the proportion of construction vehicles running empty in the Cape Town Metropolitan area. The proportion is also useful for any proposed solutions to the problem of sub-optimal logistics in construction.

Figure 2 shows that there was a total of 59% of vehicle movements which left sites empty and 29% that left full. The ratio of 59%:29% translates to a ratio of 2:1 between empty and full returns from sites. The ratio meant that for each fully loaded vehicle movement which left a site there were a corresponding 2 vehicles which left empty.

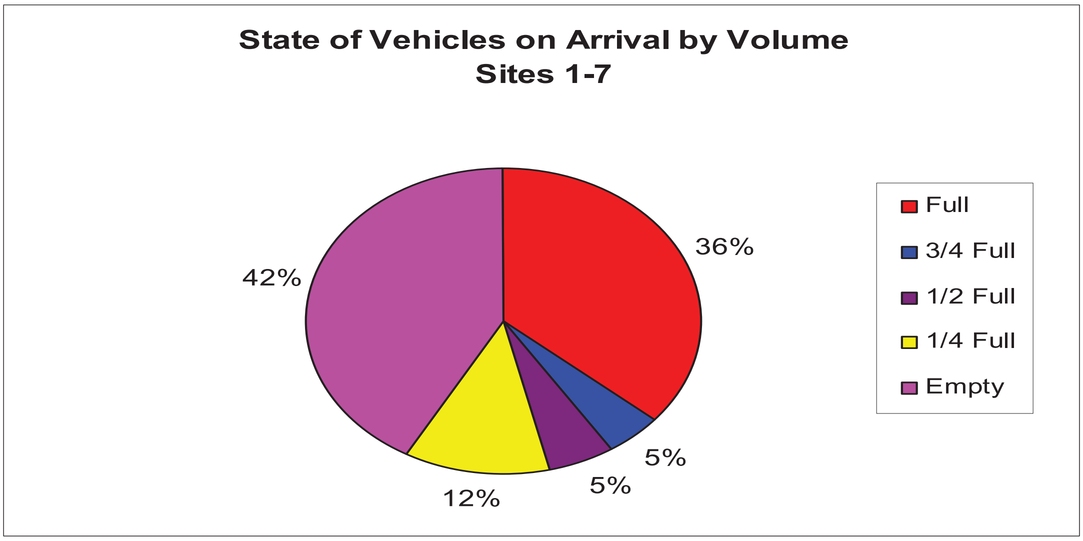

Figure 1 Levels of loading of vehicles arriving on sites

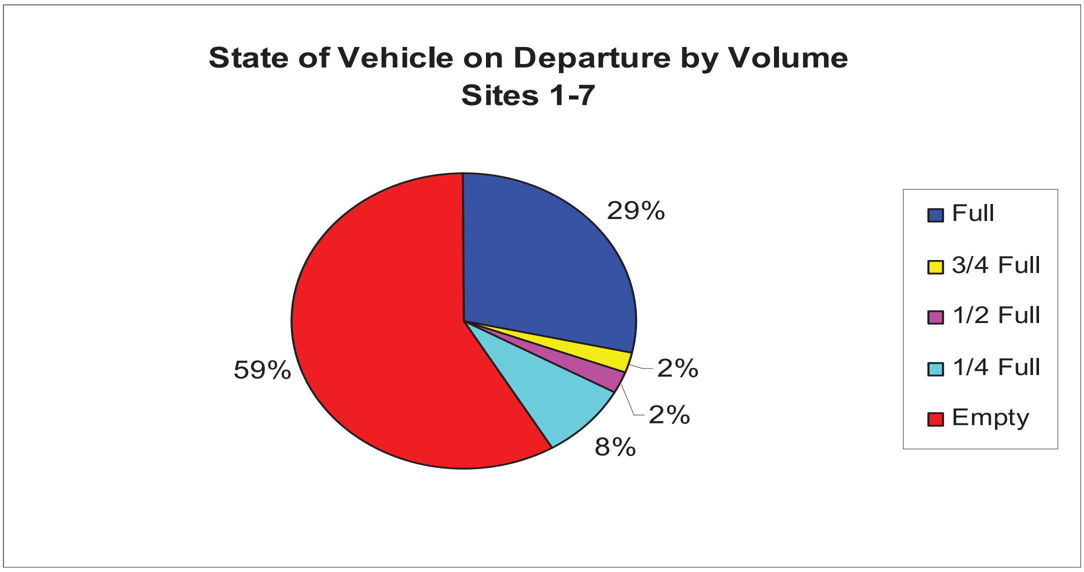

Figure 2 Levels of loading of vehicles departing sites

Figure 3 demonstrates graphically a comparison of the levels of loading of materials delivery and C&D waste removal vehicles on arrival at sites. From Figure 3 it can be deduced that some of the materials delivery and waste removal vehicles travelled to or from construction sites empty. This means that vehicle utilization in terms of loading only approximates 50% efficiency

Figure 4 shows levels of loading of materials delivery and C&D waste removal vehicles on departure from and on arrival at construction sites. From comparison of Figures 3 and 4, it can be argued, in the main, that materials delivery vehicles came to sites fully loaded and left empty.

While Figure 4 shows that materials delivery vehicles depart sites mostly empty, there are indications that some vehicles leave sites ¾, ½ or ¼ full suggesting that there may be some improvement in efficiency through load consolidation of deliveries to other sites.

The observations dealing with the two preceding charts also explain apparent anomalies in the data. For instance, from Figure 4,there were a number of materials delivery vehicles that arrived empty. One of the reasons for this was found to be that the companies concerned had directed the drivers to pick up invoice statements or conduct other non-core transportation activities.

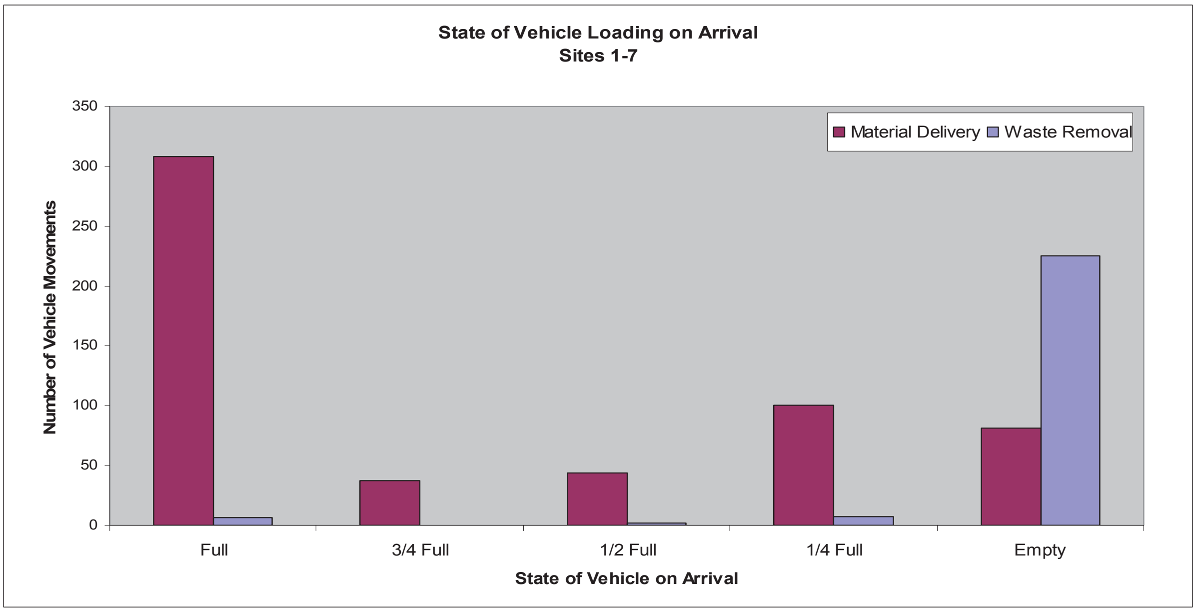

Figure 3 Comparison of loading levels of materials delivery and C&D waste removal vehicles on arrival at sites

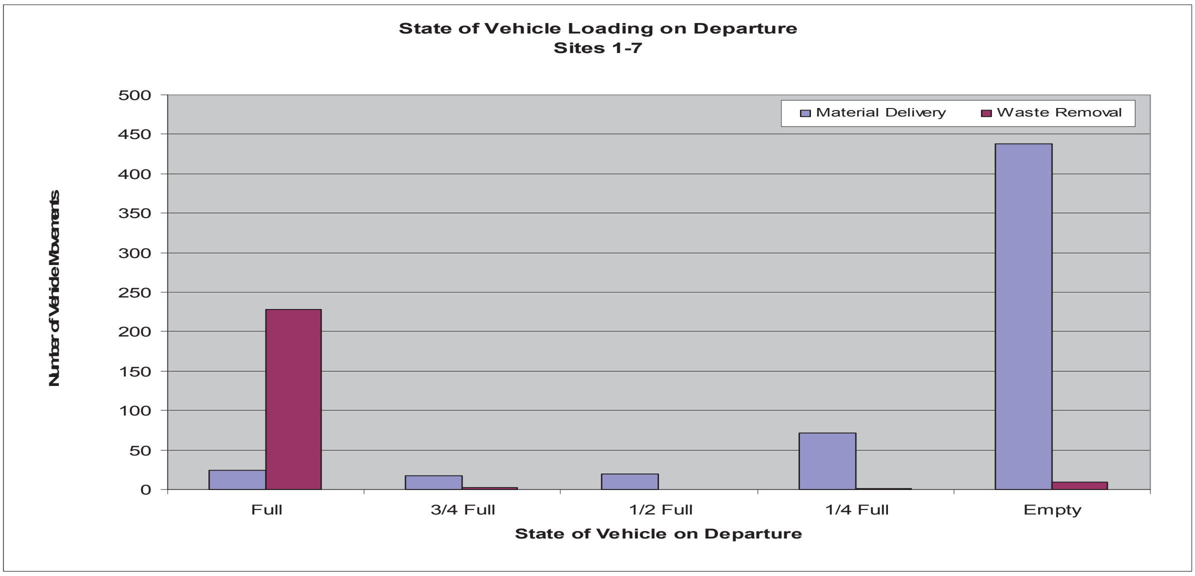

Figure 4 Loading levels of materials delivery and C&D waste removal vehicles on departure from sites

Integrated logistical analysis

Figure 5, which integrated both materials delivery and C&D waste removal vehicle arrivals and departures, made levels of construction vehicle loading become even more apparent. Materials delivery vehicles, in large part, arrived fully loaded and left empty while the opposite was true for the waste removal fleet

Prevalence of empty runs

Analysis of the levels of loading of all vehicles arriving and departing sites revealed that there was a high prevalence of empty vehicle movements on both journeys. On the forward journey, most of the empty runs were made by C&D waste removal vehicles which are traditionally single-use vehicles and therefore normally do not carry anything on their forward journey. On the return journey, most of the empty runs were of materials delivery vehicles which were returning to depots after offloading.

Further analysis showed that such a high number of empty runs for both materials delivery and C&D waste removal reduced vehicle utilisation efficiency levels to about 50%. This was a very low level of vehicle utilisation and it is important to find ways for improving the efficiency. Reducing the number of empty runs could potentially increase efficiency levels. The finding from the field study that the empty runs were on both the forward and return journeys suggested that there was scope for integration of materials delivery and C&D waste removal logistics.

The literature indicates that SCM principles can be used to improve performance and to address supply chain relationships and system improvements. The performance of materials handling and distribution, and information flow is crucial in the SCM process for the construction industry for both upstream and downstream linkages (Agapiou *et al.*, 1997; Agapiou *et al.*, 1998; Voordijk *et al.*, 2000; Vrijhoef and Koskela, 2000; Edum-Fotwe 2000; Briscoe *et al.*, 2001). These linkages provide an opportunity for detailed exploration of the construction logistics function for possible systems improvement.

From the literature it would seem that the most appropriate concept to apply to the sub-optimal materials delivery and C&D waste removal vehicle utilisation is reverse logistics. Reverse logistics is more appropriate because by utilising the empty runs of both materials delivery and C&D waste removal vehicle movements, sites can maintain the same level of materials flow while reducing the total number of vehicle transits.

PRACTICAL IMPLICATIONS OF THE RESULTS OF THE CASE STUDY

Potentially, therefore, the research reported in this paper shows that at least 36% of all traffic resulting from movement of construction vehicles on the roads in Cape Town in general could be removed. Alternatively, in terms of the industry's usage of transportation requirements, it would be possible to increase the total output of the construction sector by a third without having to increase the total number of vehicles on the roads. Both these findings are significant for the potential of the construction industry to improve the sustainable use its transport requirements.

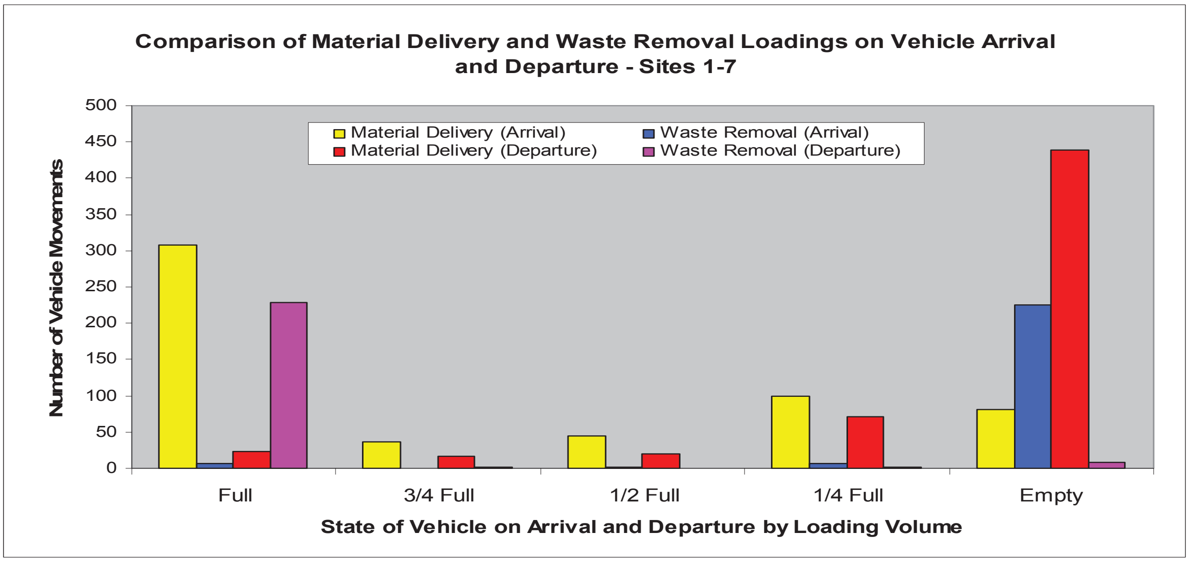

Figure 5 Comparative loading levels of materials delivery and C&D waste removal vehicles on arrival and departure at the seven sites

Further implications of the findings are that in applying reverse logistics techniques, about 36 per cent reduction in empty runs is possible. By extension, the 36 per cent potential reduction in vehicle movements implies that a benchmark for Cape Town would be that:

- about 42 per cent of all vehicles leaving construction sites should be fully loaded with waste; and
- on average, 100 per cent of all vehicles should be loaded up to 42 per cent of their payload capacity with C&D waste on their return journeys.

LIMITATIONS OF THE RESEARCH

While the introduction of supply chain management concepts such as the reverse logistics in construction is a worthwhile development, the project nature of construction poses unique challenges when compared to other industries. For instance, projects are location dependent, requiring that resource inputs be obtained in the proximity of projects. However, given the scale of the construction logistics problem, even a modest improvement would have significant results. Some of the more pertinent limitations are detailed below.

Dedicated vehicle platforms

Construction vehicles come in various shapes, sizes, types and bodies. The main vehicle types are goods vehicles and trailers. Largely, vehicle design is a response to demands of particular construction functions or their combinations. Vehicles are usually identified by the functional category in which they fall. These include ready-mix concrete trucks, general-purpose transport such as light and heavy-duty lorries, tractors and trailers, and dumpers. For the purpose of transporting materials, there is a wide choice of vehicle designs available. Most are used for transporting building materials on public highways.

One of the consequences of the above vehicle designs and configurations is that the movement of construction materials from the point of production to the point of consumption is uncoordinated and inflexible with the majority of construction materials suppliers having their own dedicated vehicles and schedules, delivering *'ad-hoc'* to various locations.

Cross contamination

There are several types of bodies used to carry various types of products. Their construction reflects the special needs and requirements of the products they transport. Body types include semi-trailers; swap bodies, box-body vans, platform trucks, multi-bucket or roll-off multi-buckets. Body types have advantages and disadvantages depending on the work to be undertaken and products to be carried.

The decision on the most suitable type of vehicle body to select for a job is based on both the stowability of the material to be carried and operating and load requirements. As a result, there is dedicated use of different body and vehicle types and independence of transport vendors resulting from problems of possible cross contamination especially between wet and dry materials, and new materials versus C&D waste.

Proposed solution to limitations

A solution to the problem of dedicated vehicle platforms and cross contamination is the use of independent third party logistics providers (3PLs) and roll-off multi-bucket container trucks (Vaidyanathan, 2005). There is also need for a paradigm shift in perceiving materials provision and waste removal as separate businesses.

Third Party Logistics Providers

By outsourcing all or much of a contractors's logistics operations to a specialized company, it is expected that efficiency gains can be made. As third party logistics providers (3PLs) are likely to synchronise their activities in geographical areas, it is likely that the use of vehicles that can resolve similar transportation requirements would be made available to adjacent sites in cities.

Roll-off multi-bucket trucks

The use of roll-off multi-bucket trucks is also espoused as providing significant benefits for construction transportation. By using multi-buckets, the problems of cross contamination can be resolved. In addition, because roll-off multi-bucket trucks need not be dedicated to specific material requirements, they also resolve the problem of dedicated platform transport e.g. the ready-mixed concrete trucks.

Need for a paradigm shift

In order for reverse logistics to be operationalised, there is need for a paradigm shift in the perception of materials delivery and waste removal. Currently the two activities are perceived to be separate issues. As a result, empty trucks go to sites to collect waste while empty materials delivery vehicles simultaneously travel from sites. By using roll-off multi-buckets as already suggested, it is possible to use the empty return journeys of materials delivery fleet to take waste to points of disposal, reclamation or recycling.

The difficulties associated with changing practices and attitudes regarding logistics in construction need to be acknowledged. Without doubt, the implementation of reverse logistics presents significant challenges to even the most technically advanced construction supply chains in the world, particularly in the context of dedicated vehicle platforms and cross contamination between new materials and C&D waste.

CONCLUSIONS

Construction is fundamentally an assembly operation utilising materials that are generally low cost and high volume, transported at irregular times to geographically different points where they are required for the production of the built environment. Consequently, transportation amounts to a substantial proportion of construction costs. Therefore, to minimise costs in the construction process, planning and forethought are essential preconditions. Construction planners, thus, need to take into account the costs of transportation as a significant element of the total process cost. Currently, construction SCM literature and practice largely ignores this aspect and other more operational issues related to logistics.

The potential savings that can accrue to the construction industry from improved transportation logistics can make this area a major source of competitive advantage. This paper has attempted to show the levels of empty running in construction transportation and highlight potential savings in this area. The primary methods of achieving these potential savings are likely to be through the adoption of logistical approaches conceptualised from supply chain management in general, and reverse logistics in particular.

In logistical terms, empty runs are an unsustainable utilization of vehicular resources. Empty journeys still utilize fuel and contribute to the wear and tear of the vehicles. In addition, such runs also generate air pollutants that affect buildings and the quality of life of people adversely. Efficiency-wise, terms vehicles running empty in one direction operate at 50% loading, while those vehicle movements running empty in both directions actually operating at 0% efficiency.

Focusing on construction vehicle movements relating to the delivery of construction materials to and the removal of C&D waste from sites, this paper established that the transportation logistic function of construction in the Cape Town area was sub-optimal.

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