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Managing logistics cost – A missing piece in Total Cost Management

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Purpose of this paper
Construction logistics is an essential part of Construction Supply Chain Management (CSCM), in both project management and costs aspects. The quantum of money that is embodied in the transportation of materials to site, which could be 39 to 58% of total logistics costs and up to 4 to 10% of the product selling price for many firms. However, limited attention has been paid to this issue in the New Zealand construction industry. The purpose of this paper is to bring logistics costs, which is under the radar of Total Cost Management (TCM), to what it deserves. The intention is to contribute to the knowledge about managing logistics costs by setting KPI using the number of vehicle movements to the construction site.

Design/methodology/approach
A case study approach was adopted with on-site observations and interviews. Observations were performed during constructions on-site from the start of construction to "hand-over" to the building owner. A selection of construction suppliers and subcontractors involved in the studied project were interviewed.

Findings and value
Data analysis of vehicle movements suggest that construction logistics costs can be estimated and managed. The total number of vehicle movements can be served as KPI measuring logistics performance in both improvement and monitoring measures

Originality/value of paper
Further analysis indicate that intrinsic and extrinsic interventions, such as implementing appropriate logistics tools that suits individual site and introducing traffic management costs, offer plausible explanations regarding how to achieve company profitability and environmental sustainability.

Keywords (no more than 5): Construction logistics, Total cost management, KPI

1 INTRODUCTION

Construction industry is a project-based industry where each project is unique. This uniqueness has direct influence over the utilisation of logistics and material transportation. Each project thus presents a logistical pattern customised to fit its operations. Since the industry does not elect where it conducts its productive activities, and therefore has to move where the work is. Construction logistics is thus an essential part of Construction Supply Chain Management, in both project management and costs aspects. Transportation is the single largest element of logistics cost (Bowersox, Closs, & Cooper, 2007). Considering that materials usually account for between 30 percent and over 50 percent of the cost of a building project (Fellows, Langford, Newcombe, & Urry, 2002), transportation costs represent approximately 39 to 58 percent of total logistics costs and up to 4 to 10 percent of the product selling price for many firms. The transportation costs of material thus represent a large percentage of the cost profile of the construction industry. Therefore, a small percentage cut in transportation costs could bring a sizable increase in profits.
However, it is noticed that there is inadequate awareness of construction logistics efficiency in New Zealand (Ying, Tookey, & Roberti, 2014). This is reflected that decisions on choosing suppliers and quantities of materials are normally made by evaluating the quoted "cost as delivered" per unit. Since the logistics cost is embodied in material cost, there is no easy way of identifying how much cost is

attributed by inefficient logistics. Furthermore, few researches addressed on measuring construction logistics (Bassioni, Price, & Hassan, 2004; Wegelius-Lehtonen, 2001). As noted by LeBoeuf (1985), "what gets measured gets done. What gets measured and fed back gets done well. What gets rewarded gets repeated", if construction logistics cost that is embedded in the material price are not addressed, there will be limited opportunity to engage the industry to improve logistics performance.

Key performance indicators (KPI) are widely used to measure performance of the construction industry. In New Zealand, a series of KPIs based on those developed in the UK have been measure over five years. Ten KPIs endorsed by the government address both project and company performance. These KPIs focus on aspects such as construction cost, construction time, predictability of cost and time, defects, client satisfaction, safety, profitability and productivity (Constructing Excellence (NZ) Ltd, 2008). Although the government intends to endorse a broad set of practical indicators, there is no KPI to address the performance of logistics costs and efficiency. Considering the significant expenditure involved in the transport related activities, it is therefore paradoxical that very limited interest in developing appropriate KPI to measure logistics performance in the construction industry. Based on earlier research, the number of vehicle movements to the construction site is proposed as KPI to measure project logistics performance. Theoretical perspectives underpinning performance measurement are discussed in subject sections, providing a debating platform of appropriate KPI assessing construction logistics. To demonstrate the application of proposed KPI, a case study is assessed. Limitations in using the proposed KPI have been identified and discussed. Finally, the significance of this paper is presented.

2 PERFORMANCE MEASUREMENTS IN CONSTRUCTION LOGISTICS

In the early 1990s, project success was considered to be linked to performance measures, which in turn were linked to project objectives. At the project level, success was measured by the project duration, monetary cost and project performance, the so called project management "iron triangle" (Atkinson, 1999). In addition to these basic criteria, researchers advocated that measures for construction project success should also include project psychosocial outcomes (such as participants' satisfaction level, and safety), time-dependent dimensions, and perspectives of stakeholders (i.e. owner, developer, contractor, user and the general public) (Lim & Mohamed, 1999; Pinto & Pinto, 1991; Shenhar, Levy, & Dvir, 1997).

The purpose of the KPIs is to enable measurement of project and organisation performance throughout the construction industry (The KPI Working Group, 2000). The process of developing KPIs has to consider the following criteria (Collin, 2002).

- KPIs are general indicators of performance that focus on critical aspects of outputs or outcomes.
- Only a limited, management number of KPIs is maintainable for regular use. Having too many and/or too complex KPIs can be time and resource consuming.
- The systematic use of KPIs is essential as the value of KPIs is almost completely derived from their consistent use over a number of projects.
- Data collection must be made as simple as possible.
- A large sample size is required to reduce the impact of project specific variables. Therefore, KPIs should be designed to use on every building project.
- For performance measurement to be effective, the measures or indictors must be accepted, understood and owned across the organisation.
- KPIs will need to evolve and it is likely that a set of KPIs will be subject to change and refinement.

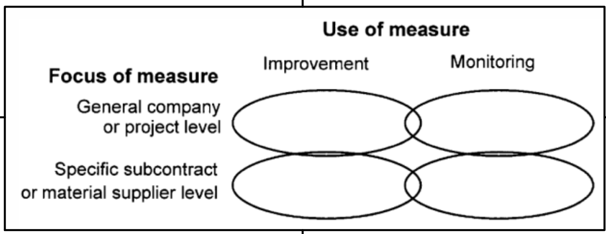
Graphic displays of KPIs need to be simple in design, easy to update and accessible.

Wegelius-Lehtonen (2001) suggests a framework for performance measurement in construction logistics, that categorised the measurements into two dimensions: use of measure and focus of measure. The first dimension, use of measure shows that application area where the measures are mainly used. It can be further divided into improvement and monitoring measures. Improvement measures are used during the development projects, while monitoring measures are used to monitor day-to-day activities. Improvement measures are employed to find out improvement potential and to realise savings, and thus can be more complicated and time-consuming to apply than monitoring measures. The second dimension of the framework is focus of measure, which illustrates the organisation where measures are used. This can be at general company/project level and/or specific subcontract or material supplier level.

Nine tested KPIs measuring construction logistics performance were listed in the article. Three KPIs are for improvement purpose, while other six are for monitoring. The framework is summarised in Figure 1.

- Logistics costs variations

- Project time efficient
- Value added
- Subcontracting percentage
- Number of invoices per day
- Amount of small invoices
- Disposal costs



- Cost of each activity through the supply chain
- Time analysis

- Reply percentage of tenders
- Amount of changes in subcontract

Figure 1. Framework for measuring construction logistics performance

It is noticed that this framework has not been applied widely in the industry. Indeed, the construction firms do not usually have continuous data collection systems for logistics measures (Wegelius-Lehtonen, 2001). In New Zealand, the practice in the industry is in line with this claim. Research points towards that the fact that the construction industry does not effectively address, or have the skills to solve, logistics problems. At present the lack of knowledge is masked by lack of immediacy in recognising that there is a problem at all. It is recognised that major barriers about awareness of logistics costs include invisible logistics costs, disconnect between investment in construction logistics and benefit, and no record data relating to logistics performance (Blumenthal & Young, 2007; Omar, Hassan, & Ballal, 2009). Consequently, KPIs measuring logistics performance that will be accepted and implemented by the industry shall be straightforward to collect and assess.

Accordingly, a model that illustrates the essential factors that have impacts on the logistics efficiency is presented in Figure 2. The total numbers of vehicle movements are represented by the size (volume) of the balloon in Figure 2. Internal 'pressure' to increase vehicle movements comes from a range of factors such as poor training and planning, inefficient loading, and logistics management strategy. The factors that will reduce the truck movements to the site (and thus the volume of the balloon in the model) are high fuel price, levies, road tolls, labour cost, environment and social costs. If these factors are tuned to its optimism in accordance with the site condition and supply chain members' circumstances, the total numbers of vehicle movements are expected to be the minimum. Consequently, the effectiveness of construction logistics to the site should be maximised. It is evident that managing the number of vehicle movements can address the challenges in planning, loading, material ordering and other essential aspects in construction logistics. Thus, total number of vehicle movements could be an appropriate KPI to measure logistics performance.

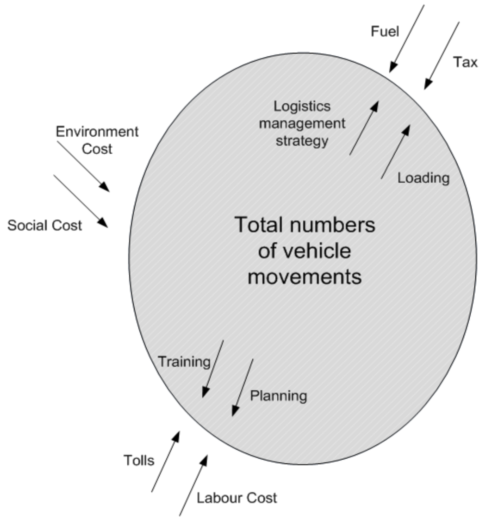


Figure 2: Factors affecting the construction logistics

3 RESEARCH METHODOLOGY

The guiding purpose of this study was to contribute to the knowledge about managing logistics costs by setting KPI using the number of vehicle movements to the construction site. The focus of the work is on identification of main performance aspects measured by total numbers of vehicle movement. It also seeks to understand why it can be used as KPI, as well as questions of how to use it in different measuring dimension. The emergence of how and why questions resulted in choosing interviews, documents, and observation as the research method, when they were seen as superior to other methods with the stated objective. The studies in this work were carried out as case study with a qualitative and quantitative approach. The purpose was to enhance knowledge of how vehicle movements process works, various aspects that this number is related to. Case studies are appropriate when the research problem requires understanding of complex phenomena that are not controlled by the researcher and when the research questions have a how and why nature (Yin, 2009).
It is important to select a critical case that can explicitly demonstrate the "how-problem" (Yin, 2003). In the first place, a commercial project in the largest city by population and area in NZ reflects typical problematic issues for construction logistics. The case study described in this paper has been developed from a commercial project hosted by AUT University. The construction site was located in central Auckland, implying special requirements in terms of logistics and physical distribution. Auckland is notable for it "Urban Sprawl" (Dixon & Dupuis, 2003; Ministry of the Environment, 2005). The city also has a substantial reliance on road transportation since public transport system has historically not seen substantial investment. The $100 million project consists of a 13 level tower block with roof top plant room surrounded with lecture theatre and student facility. The new construction integrates several existing buildings on campus. The construction has three stages: ground works, structure, and fit-out. The contract was fixed price, with the client being allowed certain flexibility in the scope without extra charge.
Also, the firm acting as main contractor of the project is the leading contracting organisation by company capitalisation and volume of work in NZ. Maintaining a dominant position in the construction industry implies either cost advantage or technical advantage over the remainder of the market. As such it may be deduced that this contractor must therefore represent NZ "Best Practice". It was anticipated that this practice may approximate World Class, but may not actually achieve it. However, it is reasonable to assume that the company represents the best competitiveness that NZ has to offer in this area.
Special attention has been paid to the numbers and patterns of vehicle movements, since it is expected that appropriate interventions to improve construction logistics can be identified through analysing these elements. The vehicle movements were recorded by the gatesperson on the site. Details such as delivery company name, date, time, truck type, materials, and activities were noted on printed table. These details were then transfer to electronic documents and analysed using MS Excel and MS Access.

4 DATA COLLECTION

Data were collected through interviews with main contractor, subcontractors and their suppliers and on-site observations. The model of “Factors affecting construction logistics”, as shown in Figure 2, was used as guidance for interviews. Questions areas about each factor were probed. The interview respondents were practitioners involving procurement of materials and plants process in the supply chains of the studied case. The procurement process includes ordering, planning, supplying and delivering the materials to the site. The respondents were chosen for their specific knowledge and position to provide relevant information about the process.

Interview participants’ characteristics are summarised in Table 1. The participants were categorised into three groups: main contractor (5.6%), subcontractor (68.5%), and material supplier (25.9%). A majority of participants were from the first tier subcontractor list. Material supplier firms were chosen from the major suppliers of the first tier subcontractors.

Characteristics	Category	Number	Percentage
Participants	Main contractor	3	5.6%
	Subcontractor	37	68.5%
	Material supplier	14	25.9%
Total		54	

Table 1: Participants’ profile

The objective of the interviews was to enhance knowledge of how the process appears and how the organisation was arranged. In addition, the interviews focused on how the contractors relates to the other ones in the supply chain. These interviews provided insight into occurrences of challenges and the causes of inefficiency in construction logistics. The participants were all skilled in their particular fields, but the process and vehicle delivery pattern of their firms’ deliveries was not well documented. This lack of documentation made systematic analysis problematic. Therefore, the need for on-site observation of vehicle movements emerged, as supply chain levels closer to the project level tend to be more adept at retaining knowledge of and experiencing with issues at the operational level than those removed from project level operations

On-site observations were performed during construction on-site, as well as during weekly coordination meetings held between the main contractor and its subcontractors. These were documented through notes, photographs and audio recording. The depicted scenes give an opportunity for participants to reflect on specific situations in retrospect. As noted by Scott and Garner (2013), observing behaviour gives opportunities to make sense of a larger context and draw conclusions that the individual subjects might have difficulty notice. Extensive observations were also made on the construction site to confirm information given by the respondents, the on-site observations also enabled gathering of information that the participants were unable or unwilling to fully disclose in interviews. These data were analysed as a whole, reduced to focus on the main objective of the paper and then presented in a reduced from.

5 KEY FINDINGS

The main aim of this paper was to contribute to the knowledge of setting the number of vehicle movement as KPI to manage logistics costs. The key findings section of the paper is focused on how construction logistics performance can be measured with in practice by assessing the number of vehicle movement to the site.

5.1 Case results of improvement measures

To measure improvement potential of delivery processes, costs and time of delivery are usually employed as KPI. However, in the construction industry, the choice of material was primarily made on the basis of lowest per unit cost “as delivered”. The cost of transportation was not isolated, and thus cannot be measured.

For the period of construction, the total number of vehicle movements to the observed site was approximately 6,300. Analysing the vehicle movements to the site, each subcontractor’s delivery can be easily sorted, with the details of vehicle type. Knowing subcontractors’ depot address, the approximate travelling distance can be identified. The vehicle operation costs vary from the vehicle category, such as large, medium and small. Thus, the transportation costs for each firm and the whole project is identified. This measurement covers both focus of measure that is for both project level and supplier/subcontractor level.

Similarly, time of delivery was analysed using same batch of data. Figure 2 illustrates deliveries occurring throughout the day following no specific pattern. The histogram appears to be multimodal a skewed normal. The histogram also shows that almost one fifth of arrivals occur before 8:00 am while 55.8% of the arrivals occur during either in the early morning (08:00am to 10:00am) or early afternoon (12:00am to 2:00pm). The diagram illustrates that the vehicle arrival times produce a smooth

distribution. Indeed, vehicles arrivals on delivery points start after 6 and increase rapidly before peaking at the time interval between 9am to 10am. Then, taper down as time passes creating a strongly skewed distribution. In the studied project, 67.8% of delivers took place before midday.
The deliveries were most carried out from 8am to 11am (38.2%), as illustrated in Figure 2, which parallels to the peak time of city traffic. These truck movements not only put extra burden on the existing saturated city traffic, but also reduce logistics efficiency. Some truck drivers complained about tight space for manoeuvring in the city roads during peak traffic. These construction vehicle movements impose negative social and environmental impact by adding to the problem of congestion and environmental pollution.

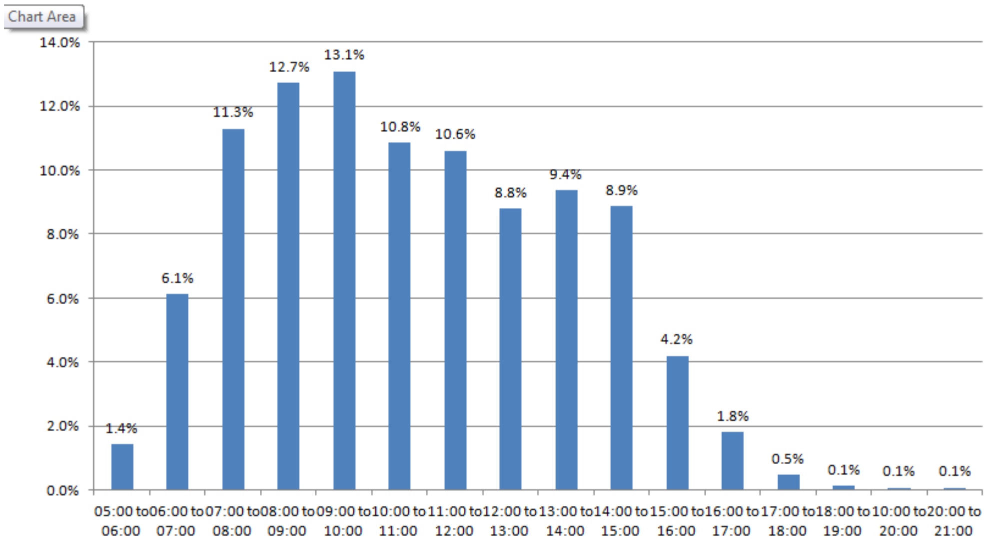


Figure 3: Truck delivery time

5.2 Case results of monitoring measures

It can also be seen by analysing the vehicle movement that being a heavily "inbound" industry, significant numbers of vehicles (86.9%) were unloading materials or equipment at the site. High percentage of these vehicles (more than 70%) drove away from the site unloaded. Furthermore, the data of vehicle movements show that in terms of transport distribution, of all vehicle movements observed, 80.1% were classified as material delivery and 18.9% as construction and demolition (C&D) waste removal. The ratio approximately to 4.2 materials delivery journeys to one waste removal journey. It was observed that the logistics of building materials and C&D waste were not integrated and the vehicle movements for both material delivery and C&D waste removal were sub-optimal. The field observation established that significant amount of materials delivery vehicle movements (more than 45%) were empty runs to their return journey and 35% of C&D waste removal vehicle movements were empty runs on their forward journey. Compare to the similar study carried out in South Africa (Shakantu, Muya, Tookey, & Bowen, 2008), it appears that the ratio at the observed site is higher than the counterparts in SA. During the construction process, some of the waste removal companies arrived site with empty bins and exchanged the filled bins back to either the landfills or company recycle plants. It could be speculated that the implementation of reverse logistics strategy is the reason of a higher ratio. However, the empty runs for both delivery and waste removal vehicles are largely the result of the failure by the construction industry to back-haul. Thus it in turn highlights the potential for integration of materials and waste, which would ultimately improve the logistics efficiency.
Compared to the construction programme, it could be seen that the numbers of delivery vehicle and its type alter accordingly. During the period of ground works and structure, large percentages of vehicles (77.2%) into the construction site were heavy vehicles with more than three axles. However, in the fit-out stage, it is observed that smaller vehicles (vans and utilities) arrived more often (41%) than previous two stages (22%). Provided that most of the materials used in the ground and structure stages were MTO and DTO with heavy volume, large vehicles were employed to deliver with reasonable efficiency. At the fit-out stage, materials were delivered in smaller amounts but more frequently. It in turn reflects the material ordering of JIT and JIC.

6 DISCUSSION

As the main aim of the paper was to promote using the total number of vehicle movement as KPI measuring logistics performance, considering this increased knowledge about logistics efficiency of the construction industry was essential to improve its performance.

Factors affecting the construction logistics, cost related factors, both monetary and non-monetary factors are not measured and largely ignored, especially the possible environmental and/or social impact occurred by the truck movement, (see Figure 2). This is reflected in the peak hour delivery and inadequate integration of delivery and C&D waste removals. Factors in the service related sector were insufficiently managed in the observed site. Materials that are order driven were planned and unloaded more efficiently than those manufacturing driven. Because of this, it was observed on the studied case that inadequate planning of material delivery and unloading hindered the project progress and caused inefficiency.

Furthermore, the number of vehicle movements is not formally monitored at construction sites in NZ. This important indicator of logistics efficiency is normally only used for the purpose of a traffic management application to the local council at the start of the project. The accuracy of this estimated number is not checked by the council either. Indeed the only reason that this study was possible was by site personnel making a special effort to monitor movements on behalf of the researcher.

These findings are related to understanding and implementing CSCM. It is noticed that there is inadequate awareness of CSCM and logistics efficiency, confirming that the critical part of operational tools and techniques for effective CSCM is not well recognised or understood (Ying, Tookey, & Roberti, 2013). Limited implementation of CSCM is largely due to lack of commitment from the management level and skills at the operational level. It is obvious that these possible improved areas did not attract enough attention from the practitioners. From the research, there is a lack of transparency in costs throughout the construction process. Decisions on choosing suppliers and quantities of materials are made by evaluating the quoted “cost as delivered” per unit. Since the cost of transportation is embodied in the delivery cost, there is no way of identifying how much cost is attributed by suboptimal transport planning. Unless there is a differentiation between the elemental costs, it is difficult to identify who benefits from an effective logistics system. Those who may be required to do things differently do not necessary gain benefits from changing to an optimal transportation planning model. None of the interview respondents were even slightly aware of the quantum of money that was embodied in the transportation of materials to site, which could be 39 to 58% of total logistics costs (Coyle, Bardi, & Jr., 2003).

6.1 Interventions for improving logistics efficiency

As discussed in the previous section, the success of construction project depends on the coordination of the on-site and external logistics. The numbers of vehicle movements is therefore capable to interpret the competence of this coordination by providing a rational base line for loading bay and crane management to facilitate logistics efficiency. As a result, the numbers of vehicle movements, in a way, links transportation, inventory and warehousing that are essential elements of effective construction logistics. However, the results of the study suggest that little attention has been paid to vehicle movements and it was not measured and managed by the practitioners.

To change existing behaviours in the industry, according to the Diffusion of Innovation (DoI) theory, the process begins with the recognition of a problem or need and through five steps: knowledge, persuasion, decision, implementation and confirmation (Rogers, 2003). The case study findings strongly emphasise the need for interventions building on the fact that the potential benefits to the industry are obvious.

The interventions can be categorised into intrinsic and extrinsic ones. The intrinsic interventions shall mainly focus on increasing the profits by improving construction logistics performance, while the extrinsic prompt the awareness of logistics costs and its efficiency.

For most practitioners, the key of improving construction logistics performance is to possess two abilities in order to operate efficient construction logistics. First, they must understand what are the available tools and techniques. Secondly, they must understand the circumstances they are in. It is not only a difficult task but also a critical one as certain tools and techniques are likely to be only appropriated under certain circumstance. The research results suggest that the industry practitioners do not recognise the importance of either construction logistics or material planning. In addition, every construction site has a different set of constraints that affect construction logistics. The nature of the constrains will depend on a number of circumstances, for example, the location of the site, the project scope, the working environment, the neighbourhood adjunct to the site, and the social policy of the client and the local government (Sullivan, Barthorpe, & Robbins, 2011). The delivery of equipment and materials may be affected by factors on and off-site, such as: Physical constraints, including the traffic systems around site (one-way systems), the lack of storage space, and restricted access due to existing structures. Indeed, the tools and techniques that are likely to be required will have to change in accordance with the circumstances change (Cox & Ireland, 1993). Therefore, the intrinsic interventions are to implement appropriate tools and techniques that suit the site circumstances. To achieve this, commitment of management level and knowledge of operational staff is necessity.

However, previous research executed in New Zealand (Ying, Tookey, & Roberti, 2013) does not present a positive environment to apply proposed intrinsic interventions. The absence of formal education and training at the management and operational level in the NZ construction industry is considered to be a key aspect of lack of theoretical understanding in CSCM and construction logistics. Thus, developing training programmes targeting both levels respectively is critical in implementing intrinsic interventions. The management level needs to understand the essence of CSCM philosophy and commit the firms to improve logistics efficiency. The training programmes for operational staff shall concentrate on intensifying planning and ordering process. These training courses would not only benefit the individuals who gain the knowledge and practice in daily work, also benefit the employed firms by reducing logistics costs. It would eventually benefit the industry as a whole for increasing logistics efficiency among various supply chains.

As noticed in the case study, the social and environmental impacts caused by construction logistics were largely unrecognised. It is evident that the NZ construction industry has not been showing very much concern about the environmental issues. Therefore, extrinsic interventions involving government interference is necessary. As, without it, there appears to be less incentive for the private sector to invest and/or investigate improved logistics methods. The main government intervention would be to bring the awareness of the hidden transportation costs embedded in material costs. This might be achieved in various ways by creating conditions for government setting the boundaries for construction logistics performance using DoI approaches. Knowledge of CSCM and logistics efficiency shall be promoted by central and local government to senior management level in the industry. Persuasions of improving performance can be done through legislation by phasing or introducing traffic management costs to recover social and environmental costs so that vehicle movements would be managed to avoid unnecessary extra costs. To set a model of best performance, it would be endorsed by decisions of setting traffic minimising plan or traffic logistics plan as one of non-price attributes for government projects procurement. It can also be reinforced in making logistics planning as an explicit part in Resource Management Consent application, especially for any projects in the CBD area. Leading by practice, the importance of improving construction logistics may be understood by the construction industry and therefore eventually change the existing behaviours.

7 CONCLUSIONS

Using the numbers of vehicle movements as guidance for data collection, the evidence provided in the case study demonstrates significant inefficiency in construction industry logistics. The main problems observed on site were low logistics efficiency for manufacturing driven materials, and suboptimal planning of material delivery and unloading. The truck movement patterns suggest that deliveries occurred mainly through morning peak hours. The patterns also indicate the inadequacy of material delivery and C&D waste integration.

Through interviews involving construction suppliers and subcontractors, the main contributors to inefficient construction logistics found in the case study were:

Factors affecting construction logistics efficiency are either inadequately managed or overlooked.

No attention was paid to the numbers of vehicle movement itself.

Insufficient awareness of CSCM and logistics efficiency.

Unawareness of logistics costs due to material costs quoted “as delivery”.

This study then proposes both intrinsic and extrinsic interventions to address the obstacles in efficient construction logistics. By introducing these interventions, it is conceivable that construction activities are conducted more sustainably. This can be achieved by maintaining the materials flow into sites while reducing the total numbers of vehicle movements.

Most notably, this is the first significant study to our knowledge to investigate construction logistics efficiency using the numbers of vehicle movements. It is evident that managing the numbers of vehicle movements can address the challenges in planning, loading, material ordering and other essential aspects in construction logistics and in turn bring a sizeable profit increases to various members in supply chains. The case study provides information about main areas of interventions necessary to enhance construction logistics. These interventions offer plausible explanations in improving logistics efficiency through optimising transportation movements to the construction site.

The work presented here focuses on understudying “what” factors are affecting the numbers of vehicle transits and “how to” agenda of procedural actions plans. It provides a starting point to begin the task of developing predictive simulations of the likely effects of various factors. Thus, further research will aim to normalise the number of vehicle movements in accordance with the characteristics of construction projects, such as site condition, construction character, and material quantities. Once this indicator can be quantified in certain accuracy, it can not only assist the practitioners to optimal material deliveries to the site, but also be used as benchmark to evaluate logistics efficiency.

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