Abstract

Purpose – The purpose of this paper is to consider the applicability of logistics management in construction and facilitate a better understanding of construction supply chains by studying the logistical functions of builders’ merchants.

Design/methodology/approach – Given that logistics application in construction is still in its infancy, conceptual understanding of the problem is a prerequisite. Thus, a grounded theory approach is followed utilising pre-existing data as a means of building a model faithful to evidence. The model is analysed by following a discrete-event simulation modelling approach.

Findings – This research demonstrates that examining supply chains from a logistics viewpoint can provide significant insight into the performance of construction supply chains. The analysis also shows that logistics costs are exponentially related to the levels of material demand and number of vehicle movements.

Research limitations/implications – The developed model has to be further investigated and tested for different scenarios. Supplementary refinements of the model are necessary in order to allow the generalisation of the results and the development of an analytical planning tool.

Practical implications – This research illustrates the increased potential of construction for benefiting from an improved capability within logistics which can lead to further developments within the field of logistics in the industry.

Originality/value – This paper considers the significant function of builders’ merchants in the supply chains in order to balance the contractor-centric research efforts that dominate existing literature and take into consideration the holistic nature of supply chain management and its operational aspects.

Keywords Supply chain management, Distribution management, Construction industry, Simulation

1. Introduction

Even the most powerful organization is reliant on the capability of its attendant supply chain (Lee et al., 1997; Bowersox et al., 2007). This fact was the outcome from Ford Motor Company’s ultimately fruitless attempt to achieve a self-sufficient firm in the
constructive reason for the introduction of the management concept of supply chain management (SCM) in the early 1980s. Following the example of both retail and manufacturing industries, construction has utilised SCM in order to improve its efficiency and competitiveness. The watershed Egan Report (Egan, 1998) in particular identified effective SCM as a critical area for improvement in construction. However, the implementation of SCM in construction is viewed primarily from the perspective of more effective procurement system selection and implementation (Green et al., 2005; Tookey and Shakantu, 2005). This, the authors contend, ignores the fundamental implicit assumptions of logistics management expertise inherent within SCM literature, which, according to Stock et al. (1998) and Bowersox et al. (2007), is a prerequisite to an effective SCM process.

This paper illustrates initial results of a PhD research project which aims to enhance the understanding of logistics processes within the UK construction industry. The paper is divided into two parts. The first describes the rationale and scope of the research; the second presents initial findings of the study. Primarily, the function of intermediaries and particularly builder’s merchants (BM) is considered. This is developed to discuss the structure of construction supply chains and their functional differences with supply chains of other industries. This comparison allows assessment of the applicability of logistics planning methods in construction. The first part concludes with the consideration of the implications of unique industry characteristics on logistics planning decisions. The second part of the paper presents the background of the development of a model for the logistics systems around BMs. Simulation is introduced as a technique offering significant utility for validating the model. Finally, simulation results are discussed and their importance for construction supply chains is evaluated. In particular, their use in the development of optimised vehicle fleets for BMs is discussed. The paper concludes with recommended future steps in construction SCM and logistics research.

2. Construction SCM and BMs

2.1 Construction SCM research

To optimise supply chain performance, it is necessary to fully understand all elements of the supply chain (Ganeshan, 1999; Ballou, 2001). Mainstream SCM research has addressed the function of all contributors to the final industrial output, including supplier organizations, manufacturers and customers. Therefore the “assembled” nature of the product is recognised, and better control over product development and delivery stages possible. Nevertheless, this is not universally applied in construction. Construction SCM research tends to focus on the end of supply chain networks, examining exclusively one element of the delivery chain, i.e. the contractor. Thus, SCM in construction currently is considered synonymous with the inbound logistics of a project organization. Primarily, the authors contend, this is because research is generally easier to undertake when the unit of study is large and easily identifiable (e.g. a contractor). This is not unreasonable since construction supply chains have many temporary, peripatetic members working in multi-organizations (Green et al., 2005; Ala-Risku and Karkkainen, 2006). However, this should not be the criterion for overlooking the benefits that effective SCM provides to stakeholders in the supply chain. Supply chains should not be viewed from the perspective of a single organization (the contractor) and its ability to control other firms (sub-contractors and
suppliers) (Parsons et al., n.d.). This viewpoint forces research and thinking away from a contractor-centric view to a holistic view of construction supply chains. Indeed, London and Kenley (2001) and O’Brien et al. (2002) highlight the need for an interdisciplinary research agenda to consider the structure and nature of the industry’s supply chains. Similarly, the adoption of SCM implies the necessity to examine all links of the supply chain cutting across organizational and industrial boundaries.

2.2 The role of BMs

Many authors have recognised construction as being fundamentally an assembly operation (Koskela, 1999; London and Kenley, 2001; Shakantu et al., 2003). In the same vein, Jones (2005) describes the supply chain as a pyramid at the apex of which sits the “major assembler”, i.e. the main contractor, followed by successive tiers of subcontractors. According to Jones, efficient information sharing is key to improved functioning of the supply chain. This is because efficient information sharing ensures that the “major assembler” is supplied with sub-assemblies, materials and building components, by the first tier suppliers effectively. The management of both information and materials flows within supply chain is essentially the definition of logistics management. BMs represent the first tier suppliers linking manufacturers and contractors. The fact that 65 per cent of all materials sold into the UK construction industry are distributed by BMs (SFC, 2006) alone, points toward BMs being a critical locus of construction supply chain research. BM companies are ranked second both in the number of firms and total employees. Their contribution to construction output is approximately 15 per cent – the same as construction products manufacturers (Construction News, 2005). These UK statistics give an idea of the order of magnitude of their importance worldwide – their function is duplicated in local and regional markets in all but centrally planned economies. BMs are a fact of construction life for the majority of countries around the world.

BMs are positioned at the nexus of the flow of building materials from the point of production (manufacturer) to the point of consumption (construction site). Thus, BMs have a distinct two-way flow to manage both upstream (money and information) and down stream (materials). Conversely, contractors are located at the very end of the supply channel and therefore manage a two-way flow but only upstream in the supply chain. BMs in essence act as a two-way “valve” governing money, information and material flows between the two extremities of the supply chain. As part of this role, BMs operate as a stock buffer for contracting firms, controlling the flow of materials within the supply chain. Furthermore, it is the BM that bears the cost and risk of holding contingency inventories. This becomes crucial when considering the frequently restricted storage capacity on site. However, there is an equally strong flow moving from the contractor to the supplier in the form of information on defects, market requirements, demand level and – critically – money. It has been noted that this interstitial positioning in the supply chain means that BMs function like “builders’ bankers”, providing extended credit terms to support the operations of contractors and subcontractors, and thus the successful completion of projects (Agapiou et al., 1998; Nicholas et al., 2000).

Table I provides additional information and summarises the function of BMs in the construction industry noted in the available literature.
3. Construction SCM and logistics

3.1 Construction logistics research

*Constructing the Team* (Latham, 1994) and *Rethinking Construction* (Egan, 1998) highlighting SCM usefulness for the construction industry were followed by a significant number of partnerships between contractors, suppliers and clients (Akintoye *et al.*, 2000). However, analysis of construction problems shows that a major part of them is associated with the supply chain and the interfaces between different parties’ operations or functions (SFC/CPA, 2005; Tah, 2005). At the operational level, logistics are considered as the control mechanism of materials and information flow through successive stages of supply chains. Industries like retailing and manufacturing have evolved huge competencies in logistics planning tools, such as electronic data interchange (EDI), material requirements planning (MRP), enterprise resource planning (ERP) systems, etc. However, the implied understanding of logistics prior to supply chain analysis is not the case in construction. Construction SCM research tends to focus on the strategic interactions of businesses considering the adversarial history of construction (Green *et al.*, 2005; Tookey and Shakantu, 2005). SCM is essentially viewed as a subset of procurement systems research. Consequently, potential benefits from logistics application are neglected - ironic given the high volume/low value nature of construction materials which makes transportation a proportionally greater component of construction materials pricing than in other industries (SACTRA, 1999; Shakantu *et al.*, 2003).

*Accelerating Change* (Egan, 2002), noted that “considerable [waste] is incurred in the industry as a result of poor logistics”. A more recent report entitled *Improving Construction Logistics*; released from the same Group (SFC/CPA, 2005) estimated that on evidence from other industries, cost savings of 10-30 per cent can be achieved through effective application of logistics management techniques. However, the report identified a fundamental lack of motivation to tackle this problem since it is not well understood. There is also a perception that the issue falls outside the remit of traditional industry competence, based on the idea that “those [required] to do things differently do not necessarily benefit” (SFC/CPA, 2005). Thus, for a solution to be achievable, a suitable approach should seek to maximise the overall profit in the supply chain, rather than optimising a single organization’s portion of it (Dainty *et al.*, 2001).
3.2 Logistics approaches
To date, research into construction logistics management has adopted two main approaches. The first focuses on the logistics within the project environment and aims to improve construction performance through efficient materials handling and delivery scheduling (Veiseth et al., 2003; Elsborg et al., 2004; Ala-Risku and Karkkainen, 2006). The second approach considers multiple echelons in the supply chain in order to improve the interactions between suppliers and clients. Evidence of this approach can be found in works like those of Agapiou et al. (1998), Wegelius-Lehtonen and Pahkala (1998) and Shakantu (2005). Thus, depending on the unit of analysis, these perspectives could be broadly termed as “project” and “supply chain” logistics management research with the former dominating existing literature. BMs are considered to act outside of the project organization and thus perceived as of subsidiary importance by a project-focused approach. As a result the logistical function of BMs, although critical, has been largely overlooked. The authors consider this to be a significant omission in the body of knowledge available in construction SCM. This becomes evident especially when considering that logistics ineffectiveness accounts for a considerable amount of waste incurred in the industry’s supply chains (Egan, 2002), while SCM has been recognised as a means for improving their performance (Egan, 1998). Therefore, the paper examines the issue of logistics from a supply chain perspective.

4. Research methodology
This paper addresses the paradoxes of the construction industry described, by including BMs in the analysis of the supply chain. It also addresses the unique suitability of construction to benefit from effective logistics management. Notwithstanding the significant knowledge that has been developed in the field of logistics in other industries the problem to be addressed could be described as the lack of understanding of construction logistics. Therefore, conceptual understanding of the problem is a requirement before further work is undertaken. Thus, the research adopts a grounded theory approach, which suggests that quantitative data can indeed be utilised so as to construct a framework faithful to evidence (Glaser and Strauss, 1967; Glaser, 2008). Initial requirements include examination/formulation of the foundations of conceptual understanding of SCM/logistics in order to achieve an effective method for adopting logistics in construction, and thus the method itself. Pre-existing data are utilised to create a theoretical logistics model incorporating the function of BMs. The model includes a series of dynamic events and relationships that describe the flow of information and materials between suppliers and construction sites. These events respond to orders received from construction sites and subsequently control the BM’s material delivery process. Input data for the model were taken from previous research by Shakantu (2005) in South Africa. Shakantu studied vehicle movements around construction sites and recorded 910 vehicle movements – 62.6 per cent of which material deliveries. The data were analysed using discrete event simulation to assess supply chain behaviour under different scenarios. The model is based on node-and-link analysis as described by Coyle et al. (2003). According to Coyle et al. (2003) complexity of a logistics system relates directly to time and distance relationships between the nodes of the system. However, the temporary nature of construction supply chains imposes particular functional requirements on contractors and BMs which in turn prevent the industry from addressing logistics. These requirements have significant
impact on the design and analysis of a logistics system and therefore, need to be discussed before the conceptualisation of the model.

5. Requirements and implications
The dyadic role of contractor, as both manufacturer and retailer of the construction product is the origin of construction SCM differentiation from “typical” SCM, e.g. in manufacturing. A contractor, acting as a retailer, should be part of a stable logistics network to ensure effectiveness of supply chain operations, estimate future demand, carry inventory over periods of low demand, and integrate transport capability. However, contractors carry out these tasks inconsistently, acting more like manufacturers as they view their main task as the “production” of the construction project. The requirement of the research is to understand the logistical function of BMs in relation to the limited logistical capability of contractors in terms of materials and information flow in the construction supply chain. This allows construction’s special characteristics to be assigned to certain logistical functions of BMs and contractors. To analyse the BM-contractor interface the most common applications for logistics planning and design were considered, including location, inventory and transportation analysis (Bowersox et al., 2007). These were identified as shown below.

5.1 Location analysis
Production facilities in construction, i.e. construction sites, are mobile. As a result, demand points (consumer locations) are largely unknown while logistics networks are highly unstable. This has a direct negative effect on logistics efficiency and makes optimum location of BMs’ distribution centres virtually impossible. Furthermore, high transportation costs force suppliers not to service remote delivery locations prompting contractors to switch to local market providers. In this case, temporary business with local BMs seems to be more effective from a cost-benefit analysis perspective; however, benefits associated with long term supply chain relationships are lost. This reality conflicts with the predominant view which focuses on strategic construction SCM.

5.2 Inventory analysis
Contractors’ ability to carry inventory is often limited or even absent, mainly due to the restricted storage capacity on site. Consequently, suppliers need to plan for sufficient inventory to satisfy demand. Generally, inventory planning is based on future demand forecasts flowing upstream from the supply chain. However, in construction, efficient inventory planning is hindered by the fact that contractors are not aware and thus, cannot communicate demand prior to contract nomination. The resultant inefficiencies, such as backlogs, capacity mismatch, unavailability of materials, etc., are critical to the performance of the whole supply chain. Further consequences are evident at construction sites where ordering and delivery practices result in delays due to lack of materials, and/or additional costs caused by express deliveries.

5.3 Transportation analysis
Transportation accounts for a significant part, often between one-third and two-thirds, of the logistics cost in several industries (Ghiani et al., 2004). In construction these costs could be significantly higher since materials and raw components are generally high volume and low value. Thus, they can generate increased demand for transportation
capacity that does not necessarily come with proportional income. Furthermore, high fluctuations of demand can result in a sporadic delivery service that can defeat the entire effort to integrate transport capability into a logistical system (Bowersox et al., 2007). According to BRE (2003), transportation of construction materials accounts for about 10-20 per cent of construction costs. When these costs are combined with the energy consumed for the transportation of construction materials, which is approximately 12 per cent of all the industrial energy used in the UK (Smith et al., 2002), then it becomes apparent that transportation implies an area of research ripe for exploitation.

Further to the above considerations, BMs’ decisions (inventory holdings, credit terms, delivery schedules, etc.) are influenced by construction industry’s characteristics. These decisions focus on longer term and strategic issues and should be considered since they affect logistics effectiveness. Silver et al. (1998) describe these decisions as structural and highlight that they involve high costs to implement and change. Table II illustrates these decisions and lists the implications of construction features on them.

As indicated from the logistics planning applications above, the special role of contractors adds to the complexity of the system. Modelling construction logistics could be considered as unravelling the way industry’s characteristics affect BMs’ structural decisions, and evaluating the influence of these decisions on the effectiveness of materials delivery systems. Hence, the model to be developed should accommodate the complexity of supply chains in terms of structure and uncertain interactions between participants.

6. Modelling the supply chain
From a macro perspective, logistics system performance is influenced by BMs’ structural decisions. From a micro perspective, logistics effectiveness depends on the time and distance relationships between the nodes of the system, such as suppliers’ and BMs’ proximity to construction sites. However, in the construction industry, the

<table>
<thead>
<tr>
<th>Structural decisions</th>
<th>Industry’s implications</th>
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</thead>
<tbody>
<tr>
<td>Warehouse location</td>
<td>Clients (contractors) operate in a geographically unspecified market</td>
</tr>
<tr>
<td></td>
<td>Point of materials consumption (construction site) constantly moves</td>
</tr>
<tr>
<td>Number of facilities</td>
<td>One-off high level demand is usual</td>
</tr>
<tr>
<td></td>
<td>Warehouses demand costly mechanical equipment</td>
</tr>
<tr>
<td>Capacity of warehouses</td>
<td>Construction materials and products are usually of high volume</td>
</tr>
<tr>
<td></td>
<td>Clients’ (contractors) storage capability is restricted</td>
</tr>
<tr>
<td></td>
<td>Construction demand is highly fluctuating</td>
</tr>
<tr>
<td>Selection of trading products</td>
<td>Projects often demand tailor-made products and equipment</td>
</tr>
<tr>
<td></td>
<td>New construction methods and materials are constantly introduced</td>
</tr>
<tr>
<td>Transportation mode selection</td>
<td>A single project may cause high demand for a particular type of material</td>
</tr>
<tr>
<td></td>
<td>High volume and low cost of materials make transportation costs relatively high</td>
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Table II. Industry’s implications on BMs structural decisions
The geographically uncertain point of demand dictates a temporary structure and locus for the logistics network and consequently, an appropriate model should demonstrate logistics effectiveness under different BM’s strategies and delivery channel’s structure. Simulation is recognised as the best solution when the system to be modelled is complex and dynamic (Oakshott, 1997). Indeed, the usefulness of simulation is based on its ability to explain supply chain behaviour under different scenarios (Kleijnen, 2005). The variability and instability of construction supply chains can be dealt with by simulation modelling (Ballou, 2001; Tah, 2005), since it:

- investigates the operational and structural changes in delivery system effectiveness;
- explores the interfaces between parties’ operations and functions;
- demonstrates the logistical processes and allows exploration of specific areas of interest; and
- provides risk-free environment for comparing alternative business strategies.

The proposed model is illustrated in Figure 1 and demonstrates the flow of materials and information between suppliers and construction sites. The system can be viewed

![Activity cycle diagram for materials delivery system](image)

**Figure 1.** Activity cycle diagram for materials delivery system
as consisted of the supplier-BM's and the BM-contractor's activity cycles. The cycles intersect in BM's inventory demonstrating the important role of BMs in construction supply chains. Active states are represented by rectangles, whilst passive states are represented by circles. The left part of the figure demonstrates the supplier-BM's activity cycle. At this point inventory is introduced into the system and forwarded to the BM-contractor's cycle. This is developed in more detail since it subsequently affects rates of productivity on site. The two cycles could be alternatively characterised as events. Since the system simulates materials and information flow, the events should take place at discrete time intervals starting with completion of the previous cycle. The utilised model could be characterised as stochastic which can then be analysed using discrete-event simulation modelling. The model is resolved using Simul8 software, developed by Simul8 Corporation. Although many simulation software packages are available, Simul8 is selected because it uses few modelling objects which however can incorporate user-defined logic. This is possible by the use of Visual Logic, Simul8's internal programming language, which allows for building logic according to the model requirements. In the above figure, active states represent work centres, which act as dynamic decision objects determining the required time for the completion of a task. Passive states operate as queues to hold work items or information waiting to be processed by a work centre. Using Visual Logic the reordering strategy and dispatch criterion are set as indicated in Figure 1.

Functional parameters controlling and driving the model are described in Table III. The table demonstrates deterministic and stochastic information needed for assessment of the model performance. In this paper, “Vehicle mix” will be considered as a deterministic but also stochastic variable.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Remarks</th>
</tr>
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<tbody>
<tr>
<td><strong>Functional parameters</strong></td>
<td></td>
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<tr>
<td>Multi drops trips</td>
<td>When more than one site is undergoing, priority is set to the site starting earlier (60:40) Vehicles of 3.5 and 7.5 t deliver to two sites, while 13 t are allowed three deliveries</td>
</tr>
<tr>
<td>Reordering policy</td>
<td>Order point and lot size selected in order that BM should not stock out during the highest demand</td>
</tr>
<tr>
<td>New site addition</td>
<td>Priorities and requirements are re-arranged</td>
</tr>
<tr>
<td><strong>Deterministic information</strong></td>
<td></td>
</tr>
<tr>
<td>Vehicles costs</td>
<td>Taken from the RHA’s cost tables (RHA, 2005)</td>
</tr>
<tr>
<td>Product unit (pu)</td>
<td>Pack of 50 bricks</td>
</tr>
<tr>
<td>Average diesel price</td>
<td>$70.67 ppl = 321.3 pp gallon (15.11.04)</td>
</tr>
<tr>
<td>Value of bricks</td>
<td>£158.00 (pack of 1,000)</td>
</tr>
<tr>
<td>Turnaround times</td>
<td>20 min for a full vehicle of 3.5 t. Then follow the increase of carrying load (minus 20 per cent when moving to bigger vehicle). Turnaround time is reduced to 50 per cent when unloading half load</td>
</tr>
<tr>
<td>Site input frequency</td>
<td>1 every 9,600 time units (minutes)</td>
</tr>
<tr>
<td><strong>Stochastic information</strong></td>
<td></td>
</tr>
<tr>
<td>Vehicles mix</td>
<td>Available vehicles – 3.5, 7.5, and 13 tonne gross vehicle (diesel)</td>
</tr>
<tr>
<td>Vehicle travel time</td>
<td>Normal distributions – relevant to specific sites</td>
</tr>
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<th>Table III. Parameters of the model and required information</th>
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<tbody>
<tr>
<td>Number of sites</td>
<td>3; located 3, 5, and 5 miles from BM's warehouse</td>
</tr>
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</table>
Furthermore, demand over the simulation period is stochastic, based on deliveries of bricks in the UK during 2004 (Office for National Statistics, 2005). Although the model has been developed for the delivery of a single product type (i.e. bricks) replicating the model would allow the creation of multiple product inventories and mixed material loads. Logistics costs included in the model are restricted to the cost of inventory; the cost of transport; and the time-related transportation costs (i.e. ownership costs like wages, depreciation, licences, overheads, etc.). All other logistics costs (costs of material handling activities; packaging, etc.) are negated in this model as being negligible compared to transport/inventory costs and in order to reduce total variables. To introduce vehicles operating costs according to loading capacity, Road Haulage Association cost tables are used (RHA, 2005), derived from annual surveys of RHA members.

7. Simulation results and analysis
The model run-length was defined by the time needed for all supply demand to be satisfied. However, a precondition was set in order to permit models incorporating vehicle mixes which cannot satisfy demand after a two days delivery promise to be automatically rejected as inadequate. This requirement is satisfied by 12 different vehicle combinations which can be studied autonomously as 12 individual models or, alternatively, a combined system of 12 different BMs acting under the same demand variations. In order to assess the impact of demand fluctuations on logistics costs, the models are tested under 5 different demand levels. The number of replications performed is the number of runs required to obtain a 95 per cent confidence interval with a width of 10 per cent. The sum of the means of these confidence intervals is presented in Figure 2 as the combined system cumulative cost.

The figure demonstrates that there is an exponential relationship between costs and demand. The study of the individual models showed that this is largely associated with the time-related costs of transportation which have a significant impact on the system’s performance. Moreover, the diagram of cumulative costs versus vehicle movements, exhibited in Figure 3, shows an exponential relationship between these factors. This in turn implies a relationship between costs and vehicle movements significant for
construction managers to consider. In essence construction materials are low value and high volume, requiring large numbers of vehicles movements in order to deliver the construction product. Thus if a construction logistics provider (such as a BM) is to turn a profit it is essential for the provider to minimise total numbers of vehicle movements and maximise the loading of the vehicle. By induction, operational systems using high numbers of deliveries (i.e. JIT) are inappropriate for BMs and other up stream suppliers who would not benefit from the adoption of such an approach. To a certain extent the position adopted by SFC/CPA (2005) and its assertion that “there is no real incentive to tackle this [the logistics problem in construction]” would appear to be vindicated.

When “vehicle mix” is considered as a stochastic variable, the model represents a single BM operating under the same demand conditions studied earlier. The same criteria as above are also used for defining the run-length and the number of model replications. The impact of demand fluctuations on costs over all vehicle combinations are presented as the mean of confidence intervals in Figure 4. The exponential model that best fits this data is found to be: \( Y = a + b \exp^{cX} \), where \( a = 1.95 \times 10^4 \), \( b = 2.70 \times 10^1 \), \( c = 2.57 \times 10^{-3} \), while the coefficient of determination \( r^2 = 0.99 \). The analysis was performed on the LAB Fit (Silva and Silva, 2006), developed for analysis of experimental data. This model was used to predict further cost values for different levels of demand. The curves of sales and profit are also depicted in Figure 4.

Sales are analogous to demand since no quantity discounts were included in what may be considered to be a basic model of the process. A more complex model in which a price break discount for bulk purchases could be included was considered. However it was decided that such an inclusion would unnecessarily complicate the development of the model whilst limited additional information may have been generated by its inclusion in the development process. The generated profit is calculated by subtracting the cost of operations from the sales. From the profit curve it becomes apparent that there is no profit generated for the lower and the higher levels of demand. Moreover, the curve enables the identification of the range of demand levels where the BM maximises profit. The physical interpretation of the figure is that the BM bears a basic cost for holding inventory and maintaining the fleet, even when there are no

![Figure 3. Cumulative average costs over all replications by vehicle movements](image.png)
sales. On the other hand, high vehicle operation costs (i.e. substantial distances with minimal loads or lower unit sales price) compared with accrued revenues, and rapidly the BM's investment in vehicles is likely to exceed profit.

The cost and vehicles movements in relation to the exponential model also seem to fit these data very well. This is illustrated in Figure 5. The model given by LAB Fit is \( Y = c + a \exp^{bX} \), where \( a = 2.59 \times 10^6 \), \( b = -4.21 \times 10^3 \), \( c = 1.99 \times 10^4 \), while the coefficient of determination \( r^2 = 0.99 \). For the construction industry, this outcome reveals, as expected from the cumulative result, the inappropriateness of operational systems which incorporate a high number of deliveries. Again reinforcing the inappropriateness of JIT, one of the key suggested “improvements” possible in
construction industry supply chains according to some, from the operational logistics standpoint.

8. Conclusions
The paper demonstrated that examining construction operations and production from a logistics standpoint can provide important insights into the performance of the industry’s supply chains. Certainly, the fragmented nature of the industry and the temporary character of its organizations contravene fundamental knowledge of logistics management. However, this should not be viewed as an a priori compromise, but rather as an exploratory challenge for the whole industry and research community, especially, since there is a belief that potential benefits from improving logistics could include substantial savings up to 30 per cent (SFC/CPA, 2005). As the paper revealed, for a logistics approach to be applicable two fundamental requirements exist. First, the association of special industry features to specific logistical functions of the supply chain and second, the need for expanding the scope of logistics management outside the project environment. Moreover, the findings illustrated how logistics costs are affected from changes in demand and vehicle fleet size and characteristics indicating that simulation can be used as a tool in order to manage complex and unstable supply chains, an everlasting source of problems for the construction industry. However, the model presented here considered logistics costs associated with a single type of product and under certain simulation scenarios. Although this information was incorporated in order to reduce complexity at the current stage of the study, a generalisable outcome would necessitate these assumptions to be removed. This requires a structural, economical and organizational analysis of the industry’s supply chains which is crucial in order knowledge developed in the field of logistics in other industries to be bequeathed to construction. This will help to address operational inefficiencies associated with interfaces between different parties of construction supply chain and provide opportunities for all stakeholders to achieve lower costs, higher profits and better value for construction clients.

References


**About the authors**

Christos Vidalakis is a Research Fellow at the University of the West of England, Bristol, where he conducts research in the area of supply chain management and sustainable construction procurement. He received a BSc (Hons) in Civil Engineering from the University of Patras and an MSc in Project Management from Heriot-Watt University. Also, as a PhD Candidate at Glasgow Caledonian University, he is exploring the application of logistics management in construction. His thesis, to be defended in 2010, aims to provide an understanding of the logistics processes of
the UK construction industry and a simulation tool for optimising construction logistics planning. Christos Vidalakis is the corresponding author and can be contacted at: christos.vidalakis@uwe.ac.uk

John E. Tookey is an Associate Professor in Construction Management at Auckland University of Technology. He holds a PhD in Industrial Engineering from the University of Bradford and he conducts research and publishes regularly in the area of supply chain and logistics management in construction. His interests also include a range of areas within the Construction Management discipline including procurement processes, quality management and implementation, transaction cost analysis, and the implementation of tracking technologies in the construction supply chain.

James Sommerville is a Professor and holds a Chair in Construction Management at the School of the Built and Natural Environment, Glasgow Caledonian University. He holds a PhD from Heriot-Watt University and has extensive industrial experience in the UK and Middle East. His research includes work on the management of construction enterprises, people within construction organizations, and the implementation of IT within the construction industry. He has numerous research publications in journals and at conferences on defects management, business process mapping, customer relationship management, total quality management, stress, women in construction, conflict, and recruitment.

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