LOGISTICS CENTERS TO SUPPORT PROJECT-BASED PRODUCTION IN THE CONSTRUCTION INDUSTRY

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ABSTRACT: With the advancement of information technology and increased market competition, construction companies are driven to employ supply chain management strategies to seek competitive advantage. Managing logistics is one component at the core of such strategies. An effective logistics system ensures delivery of the right products and services to the right customers at the right time while minimizing costs and rewarding all participants based on value added to the supply chain. As a component of a logistics system, logistics centres can serve the construction industry by offering services such as: storage, transport, distribution, assembly, kitting, consolidation, sorting, breaking bulk, cross-docking, and e-commerce.

This paper focuses on the role logistics centres may play and the impact they may have on construction supply chains. Construction companies may configure their logistics centres in different ways to match their global and local supply chain strategy, while addressing challenges posed by variation in demand and supply for material, equipment, and services. A hypothesis is that logistics centres are underused in this industry, yet may offer considerable advantage. The ultimate aim of the research that is reported on here is developing a logistics system to support project-based production needs. The authors present a simulation model of a logistic centre that supports multiple site stores on different construction projects facing variations in supply lead times. The objective of the simulation is to find an approach to reduce material management costs while avoiding resource shortages, and enhancing both reliability and responsiveness of the supply chain.

KEY WORDS

Logistics centre, supply chain management, logistics, lean construction, simulation.

INTRODUCTION AND LOGISTICS OVERVIEW

As business processes are becoming global, competition is turning fierce, and information technology is advancing continuously, companies are looking for business schemes, such as supply chain management, to establish an edge over competitors and respond to new market challenges. Supply chain management involves firms working collaboratively in a network of interrelated processes to achieve global goals such as reducing total costs, decreasing total lead times, improving total profits, etc. while meeting customer value and

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rewarding all members of the chain (after Tommelein et al. 2003 p. 2) . Considered the back bone of supply chain management, logistics makes these goals possible by efficiently moving materials, services, funds and information up and down the supply chain. Logistics creates value within the supply chain through managing customer service, orders, inventory, transportation, storage, handling, packaging, information, forecasting, production planning, purchasing, cross docking, repackaging, preassembly, facility location and distribution (Bowersox et al. 2007, Gourdin 2006, and Simchi-Levi et al. 2003).

The history of logistics goes back to times of war when troops had to be supported. Logistics nowadays is closely connected with satisfying the customer (Gourdin 2006). Logistics is considered to be at the core of any firm's value chain. Figure 1 shows the primary and supporting activities in a value chain. The value chain consists of a unique set of activities that an enterprise performs on a day-to-day basis to achieve competitive advantage. Logistics thus directly affects a firm's sustainable competitive advantage by adding value to its value chain (Porter 1985).The fast development of knowledge in logistics, largely attributed to the fast advancement in information technology, is an important driver of logistics management (Gourdin 2006 and Bowersox et al. 1999).

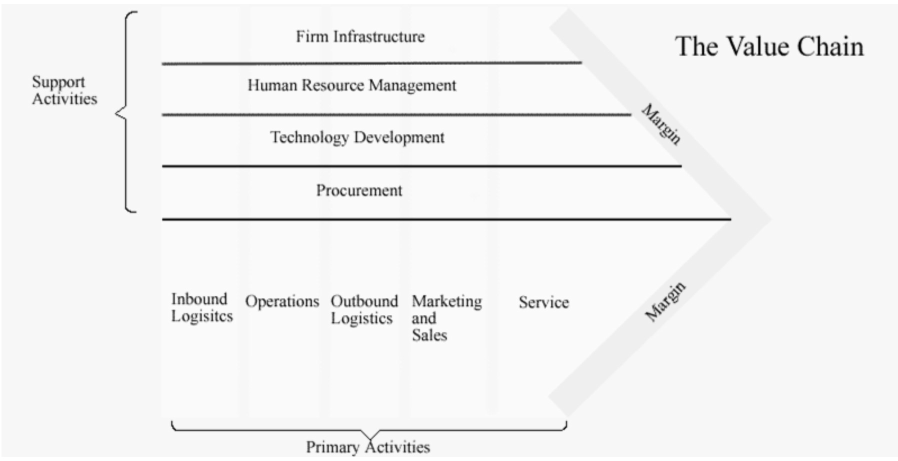

Figure 1: The Value Chain (adopted from Porter 1985)

This paper introduces the concept of a logistics centre as an integral part of a logistics system aimed at enabling optimal functioning of supply chains. A definition of a logistics centre is provided together with potential functions and configurations. The paper also introduces the role of a logistics centre in the construction industry and the impact it may have on supply chain performance. A simulation model, based on a case study, is presented to explore how the use of a logistics centre may impact a construction supply chain that faces variation in supply lead times.

LOGISTICS CENTERS

The term "logistics centre" is not new. It has been used to describe centres performing a broad spectrum of logistical functions and business processes. The term combines "logistics," which refers to all operations required to deliver products or services excluding producing the goods or performing the services, and "centre," which stands for "a place where a particular activity is concentrated" (Baudin 2004, American Heritage Dictionary 1992).

"Logistics centre" is used by many authors to describe facilities performing different functions. Definitions primarily fall into two categories. The first considers a "logistic centre" to be part of transportation infrastructure. A logistics centre is a focal point for material flow streams in a logistics chain. It thereby provides access to different shipment modes, performs broad logistic functions, serves a wide range of users, presents information technology solutions, and offers value added services (Medute 2005 and Europlatfroms 2004). The second portrays a "logistics centre" as a stimulus to generate business. A logistics centre acts as an impulse for business and economic development. Since not all companies are able to build their own logistics centres or acquire the latest support technologies (software, radio frequency identification systems, real time communication network, etc.) and management skills, logistics centres offer these services without the added risk or infrastructure costs (Medute 2005).

A logistics centre can fall under either definition depending on the role it plays in the supply chain. This role is closely related to configuration and function of the logistics centre.

CONFIGURATION AND FUNCTION

As companies in the construction industry look for ways to reduce lead time, delivery uncertainty and logistics costs, the need for logistics centres is expected to increase. (Kondratowicz 2003). Logistics centres promise benefits to a logistics network in terms of economies of scale, advanced technological systems, and merits of pooling tactics.

Managers of logistics centres should work closely with owners, builders, designers, and contractors to supply material and equipment on time (Walsh et al. 2004). As logistics centres carry materials and deliver them when required, they can play a key role in the development of lean networks with supply companies, shipment firms, construction sites, and other logistics providers.

Logistics centres can be configured to provide a wide range of functions such as: storage, transport, distribution, assembly, direct shipment, shipment with milk runs, cargo consolidation, sorting, break-bulk, distribution network management/vehicle routing, delivery, package tracking, e-commerce services, etc. One or more of these functions can be employed at a logistics centre to cater for requirements in a specific supply chain. A brief description follows of each function and its possible use in a construction supply chain. Further research is required to explore the full capability and benefits of these configurations.

Storage: storage at a logistics centre can reduce supply chain costs due to reduction in inventory costs and possible economies of scale in purchasing. Variations in demand across different projects are combined into one pool of inventory resulting in lower levels of safety stock required to compensate for variations. Thus total inventory is lowered due to pooling or aggregation.

Transport: Depending on the location and function of a logistics centre, transportation costs can be lower or higher depending on the trade-off between inbound and outbound transportation costs. A shorter lead time is also possible but is related to location and other factors.

Distribution: Various distribution methods can be applied such as direct shipment or milk runs. Material stored at a logistics centre can be supplied just in time (JIT) due to possible proximity to projects.

Assembly and kitting: Logistics centres can have assembly capability to supply made-to-order products with a short lead time. Made-to-stock products can be kitted at logistics centres with engineered-to-order products to form assembly packages. In addition, logistics centres can be used to adjust assemblies facing design changes thus, reducing the adverse impact of changes that are ubiquitous in construction.

Consolidation, sorting, and breaking bulk: On one hand, material ordered in bulk at possibly a discounted rate can be separated at the logistics centre, sorted, and then shipped to the designated project. On the other hand, material coming from different suppliers can be consolidated and then shipped to a certain project.

Distribution network management/vehicle routing: A logistics centre can be designed to handle and optimize material distribution by assigning material packages to vehicles and choosing the best route. Vehicle routes can use milk runs or direct shipment based on project needs.

Delivery and package tracking: Using information systems (e.g., radio frequency identification or RFID), a logistics centre can track the status of material and vehicles throughout the supply chain. This can increase delivery reliability when it comes to correct material orders and timely deliveries.

E-commerce services: E-commerce adds value by replacing physical paper-handling practices such as ordering with electronic ones, thus reducing cost and time. When equipped with the necessary information systems, a logistics centre can apply e-commerce services such as vender managed inventory to reduce lead times and costs while increasing supply chain reliability.

VARIATIONS IN SUPPLY AND DEMAND

Exploring the role and impact of a logistics centre on construction supply chains is beneficial for construction companies aiming to improve their supply chain management practices. The construction industry is characterized by high variations in supply and demand for resources such as material, equipment, and services thus posing a set of challenges on the logistics network. Uncertainty undermines efficiency and responsiveness of a supply chain. It causes supply-demand mismatches leading to increased lead times, underutilisation of resources, increased supply chain costs, and unhappy customers.

Demand forecast for resources on construction projects is directly related to construction schedules. Construction schedules assume a certain start date and duration for site activities. Each activity represents a certain scope of work and requires an amount of resources including material. Combining the amount of materials required as needed to support activity progress is called "material histograms". Activity start and duration are uncertain due to uncertainty in work scope definition, working environment (underground conditions, weather, etc.), changing information, resource allocation, activity constraints, activity sequence/dependence, means and methods used. This variation in construction schedules results in relative variation in material histograms (also see Zouein and Tommelein 1993). Many uncertainty parameters that affect activity start date, duration, and material consumption are shared among different activities and thus lead to activity correlation and interdependency (Lingguang et al. 2005, Ayyub et al. 1994).

Whenever durations of site construction operations vary from planned schedules, complexity is added to material management due to changes in material delivery dates. Construction is still considered a craft-based industry with practices being more variable and uncertain than those in manufacturing. High swings in material demand on construction projects are related to activity planning and execution and are different from demand swings in retail which can be cyclical or seasonal. Moreover, distribution channels are long and convoluted despite the trend for more consolidation, e.g., through the use of information systems (Ko et al. 2004 and Schmenner 1995).

Variations in supply for materials and services affects progress on construction projects due to fluctuations in capacity, market status, delivery times, product availability, delivery lead time, etc.

Applying lean techniques such as the Last Planner™ system can increase the reliability of demand forecast/project scheduling and supply by performing constraints analysis. Constraints affecting the start, progress, and completion of activities are analyzed several weeks before planned start date to confirm their availability, thus shielding construction activities from variations. (Ballard 1995)

Mismatches between supply and demand in construction are sometimes compensated for by using a combination of inventory, time, and capacity buffers. Creating these buffers is costly and counterproductive for construction operations as they often lead to complacency. When contractors try to hedge against variation by reducing lead time and process execution time in order to reduce the likelihood of changes, they may increase operation costs (Ko and Ballard 2004).

Since the availability of materials influences activity execution, the highest price that a construction project can pay for uncertainty and randomness is not having the required resource when required. Thus, methods to improve a logistics network such as employing a logistics centre should be explored to understand the potential benefits they can add to a construction supply chain.

SIMULATION MODEL FOR A LOGISTICS CENTER SUPPORTING SITE STORES

The simulation model used in this paper is an exploratory model based on a case study simulating a supply chain of project site stores, suppliers and a logistics centre. The objective of building this model is to understand the circumstances where logistics centres are worthwhile employing, in terms of economic feasibility, in supply chains facing variations in supply. Two supply chain configurations are presented and analyzed. The first (Figure 2) comprises stores that are periodically replenished from a logistics centre carrying the required inventory to supply multiple project site stores. The second (Figure 3) represents a decentralized system where stores are directly supplied from different suppliers. Site stores shown in these models are assumed to carry high demand made-to-stock products that are relatively small in size, such as small tools, fasteners, consumables, personal protective equipment, etc.

Material shortages are expensive in construction resulting in lost production, lost resources, execution of out-of-sequence activities, delay in subsequent activities, etc. Consequently, avoiding material stock-outs presents an important opportunity for study. At the same time space at site stores for the duration of a project is also costly. Therefore, finding the optimum capacity of site stores is crucial for efficient materials management.

Site stores have a maximum space capacity for inventory storage. We are interested in finding the optimum store size to fit different material types while meeting variable demand during a project.

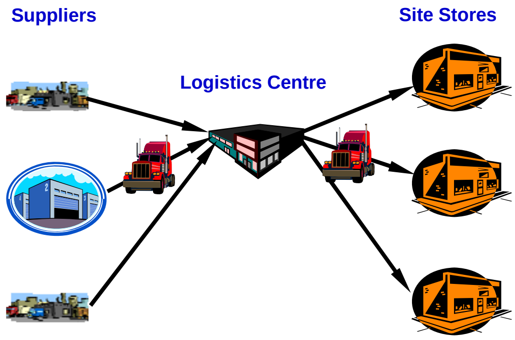

Figure 2: Logistics centre serving multiple project site stores

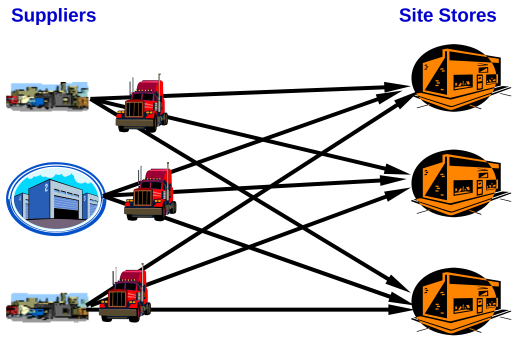

Figure 3: Decentralized system of suppliers supporting site stores

Two simulation models, represented graphically in figures 4 and 5 were developed to understand the system's operation modelling randomness and dynamics of these two supply chains. The graphs represent surrogates of the real systems and helpful in improving logic checking. Simulation reinforces our knowledge utilizing the modelling power of graphical techniques. Analysis of the simulation model provides insights into the system performance and its limitations (Shruben et al. 2005).

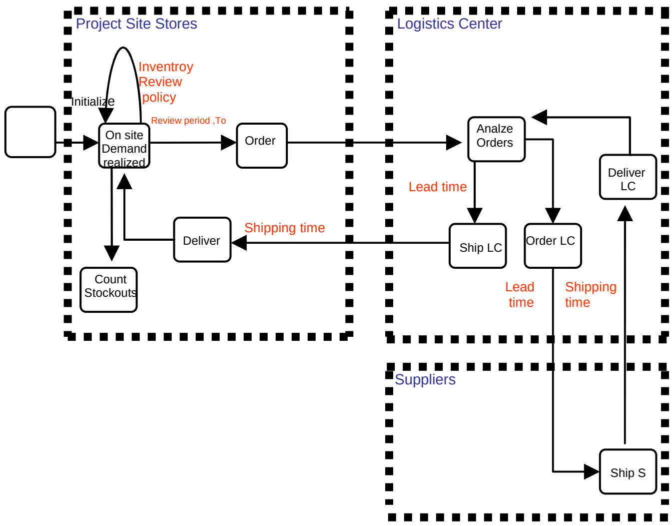

Figure 4: Model 1 depicting a logistics centre supporting site stores.

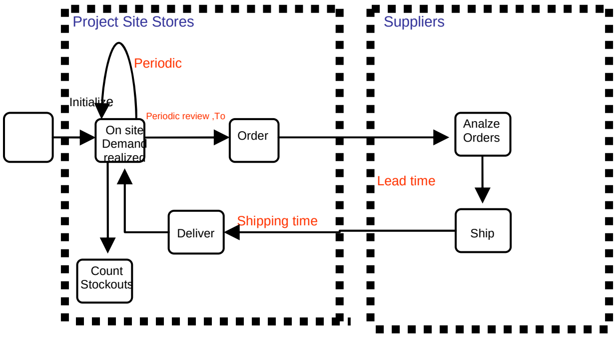

Figure 5: Model 2 representing a decentralized system of suppliers supporting site stores.

MODEL WALK THROUGH

The simulation model comprises the following activities:

Initialize: defines system characteristics, variables and configurations such as material types, projects served, number of suppliers and other input data required to simulate the system, such as lead times, costs involved, demand estimates, locations, etc.

Demand: generates a demand for each material on each project every period (To) (periodic replenishment is used but other replenishment policies might also be applied). Inventory is decremented by the corresponding demand as long as the stock is not depleted. Back log orders are recorded to be included in following shipments. At each period inventory holding cost is charged for each material held in a project's site store.

Demand generated is compared to available inventory. If enough inventory is available to match demand, inventory level would be reduced by the demand amount. If inventory is less than generated demand, inventory would be depleted. Back log is recorded equal to the deficit between demand and available inventory.

Count Stock out: If project demand is not met at a site store or demand from a project site store, a stock out is recorded.

Order: A project order comprising the estimated demand material on a project is sent every period (To) to the logistics centre. The ordered quantity covers demand during lead time in addition to safety stock required to cater for variation in demand during lead-time.

Analyze order: checks if the required amount ordered for a material is available at the logistics centre in model 1 and at the supplier in model 2. Material quantities ordered by a project P for a period (To) are consolidated into a shipment and sent to the site store. Orders are checked against available capacity at each project site store. Orders are adjusted to match the available capacity, to include backlog orders and to replenish safety stock.

Ship: decrements inventory at the logistics centre in model 1 and at the supplier in model 2 by the ordered amount. Inventory holding costs for the current period are then evaluated.

Deliver: After a lead time of (Tlc/p), material is delivered to site store and inventory is incremented. Shipping costs are evaluated

Order LC: An order for material estimated is sent from the logistics centre every period (To) to suppliers.

Ship S: After a lead time Tl[S/LC], orders are consolidated at the supplier and sent to the logistics centre. Shipping costs are evaluated.

Deliver LC: When materials are delivered to the logistics centre after a time of Ts[S/LC], inventory is incremented by the ordered amount. Inventory costs are evaluated.

SIMULATION EXERCISE

The objective of this simulation exercise is to determine the optimum site store capacity where stock-outs at site stores and at the logistics centre are unlikely to occur and to find out the impact of a logistics centre in a supply chain where lead times from suppliers are variable. Moreover, the simulation is expected to show the impact of the logistic centre on site store capacity. Average inventory at site stores and at the logistics centre are calculated in both systems for comparison purposes.

Two specific models are compared where model 1,shown in figures 2 and 4, represents a supply chain formed of one supplier, three project site stores and one logistics centre. Model 2, shown in figures 3 and 5, represents a decentralized system of three project site store supported by one supplier. Inventory is reviewed periodically every time To.

The model assumptions and initial parameters were introduced for simulation purposes focusing on the impact of variations in supply and the role of a logistics centre.

- In model 1 and model 2, the supplier is assumed to supply orders within a variable lead time but the supplier does not stock-out.
- In model 1, the lead time for supply from the logistic centre to site stores is assumed to be one day while the lead time from supplier to the logistics centre is assumed to be (0.8 + 0.4*RND) where RND is a random variable between 0 and 1 . The average lead time is thus one day with a standard deviation of 0.12 days.
- In model 2, the lead time from supplier to site stores is also assumed to be (0.8 + 0.4*RND)with an average lead time of one day and a standard deviation of 0.12 days.
- Periodic review time To is assumed to be one day.
- Demand for each project is assumed to stand for combined demand of different material. Space capacity would be determined by multiplying material quantity by a space/unit ratio specific for each material type. All materials are assumed to have the same ratio in this model.
- Demand generated is assumed to be uniform between a lower limit A and upper limit B. Demand= A + (B-A)* RND. Where RND is random number generated between 0 and 1. The mean demand would then be AVG= (A+B)/ 2 and the standard deviation STD= (B-A)/2*√3.These limits change across stages of construction. Demand between projects is assumed independent. An example of demand limits for period one are shown in table 1.

Table 1: Demand for first period across three projects

Time Period	Demand for Project 1		Demand for Project 2		Demand for Project 3	
	A	B-A	A	B-A	A	B-A
1	8	3	10	4	12	3

SIMULATION DISCUSSION AND RESULTS

Optimum capacities of project site stores, where stock-outs at the logistics centre and at site stores are unlikely to occur, are shown in figure 6 for two networks facing variations in supply: one employing a logistics centre and the other representing a decentralized system. Capacities calculated over 10 simulation runs show a significant decrease when employing a logistics centre. The increase in supply chain variations leads to an increase in capacity of site stores in the decentralized system due to increase in safety stock. Site stores capacities for lower in model 1 since an aggregate safety stock is held at the logistics centre to compensate for supply variations.

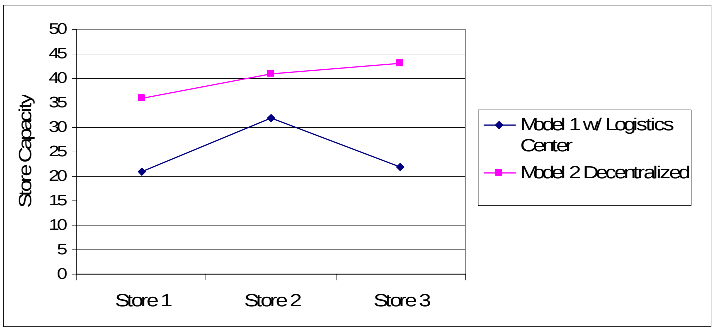

Figure 6: Optimum site store capacity in the two systems

Average inventory at site stores and at the logistics centre are calculated in both systems for comparison purposes. The three series shown in figure 7 represent simulation results of 10 runs for the following: time average inventory at site stores for model 1 without inventory at the logistics centre, time average inventory at site stores for model 2, and time average inventory at site stores for model 1 with inventory at the logistics centre.

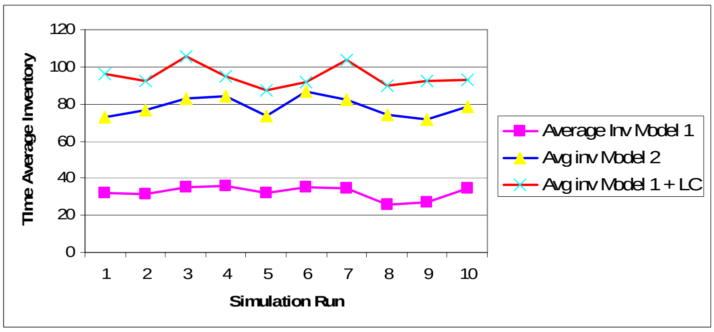

Figure 7: Average system inventory for 10 different simulation runs.

Simulation results, presented in figure 7, show that average material inventory in each project site store is lower when a logistics centre is utilized. However, total inventory in the system, including inventory held at the logistics centre, is higher in model 1. This result is related to level of variations in supply and would favour the system employing a logistics centre as variations in supply increase.

Although the total inventory level for the decentralized system is lower, it may correspond to higher inventory costs when holding costs at the logistics centre are lower than those at site stores.

Results from this exploratory model highlight some benefits when employing a logistics centre related to reduction of inventory costs as a result of material aggregation from different projects facing variations in supply. However, cost reduction due to economies of scale when employing a logistics centre can also have a significant impact on reducing supply chain costs.

CONCLUSIONS AND RECOMMENDATIONS

This paper has introduced the role that logistics centres may play in construction supply chains. Different configurations and functions of logistics centres were presented along with the need of supply chain methods to face variations of supply and demand for materials and services.

Simulation models presented in this paper are exploratory and intended to determine the optimum capacity for sites stores carrying high demand and small size material. Although site store capacity has a cost on construction projects, penalty costs for material shortages are high in construction due to the adverse effects of shortages on project progress and completion.

Results from the simulation exercise indicate some potential benefits of employing a logistics centre as a result of material aggregation on different projects to face variations in supply. However, the impact of other benefits attributed to logistics centres such as economies of scale was not explored.

Conclusions presented are based on the simulated models and embedded assumptions. Further research is required to characterize the nature of demand and supply in construction and understand the impact of logistics centres on construction supply chains and the suitable configuration of logistics centre to cater for different project needs.

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