Importance of Planning for the Transport Stage in Procurement of Construction Materials

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Abstract -

The use of logistics milestones, as predecessors for construction works, is gaining popularity to improve the control over the material procurement stage and minimize the risks of delay in the project completion resulting from late material deliveries. Transportation is an important phase in the procurement process which can account for up to 20% of the total project expenditure in some industrial construction projects. However, despite its importance, transportation is usually overlooked when planning the material procurement stage and evaluating the potential risks of delay. This study evaluates the current practices in managing transportation stage of the construction material procurement process and the perception of the industry practitioners about the importance of considering material transportation in project planning using the results of a limited systematic survey. In addition, the importance of transportation in the procurement of construction materials is studied by considering the actual data on shipment of construction materials/components in two industrial projects. Results indicate that material handling procedures adopted in industry are highly disorganized and transportation variables are ineffectively articulated. The results highlight the need for methods to plan, monitor and control the transportation stage as an independent activity in the material's life cycle. Besides the travelling distance, weight, dimension, mode of transportation, and terms of delivery were identified as the main factors affecting the transportation of the construction materials.

Keywords -

Transportation; Construction Material; Supply Chain Management; Planning

1 Introduction

Construction contractors are increasingly engaged in supply of material from diverse sources around the world and statistics have declared that more than 65% of a construction project budget is spent on procurement of materials [1]. This process starts with design and engineering pursued at manufacturers' workshop, and ends with a series of journeys from factories to the construction site. Planning such a long supply chain requires scrutinizing all the stages involved in terms of time and costs [2].

On the other hand, delay in construction projects has always been an issue of concern in both academia and industry. Late delivery of construction materials and components has been identified as one of the main causes of delay in major industrial construction projects. Therefore, timely delivery of materials is essential to ensure meeting completion date of construction activities [3].

However, on-time delivery of materials is a complicated job and requires planning, monitoring and control of different stages of the supply chain including the transportation stage [4]. Off-site transportation of materials has been estimated to account for 10 to 20% of the total project expenditure in typical industrial construction projects [5]. However, despite its importance, little has been done to investigate the efficiency of the current transportation management practice and potential strategies to improve the latter. This study aims to investigate the current practice in planning of off-site transportation in the industrial construction projects and identify the main factors influencing the efficiency of the transportation stage. The available literature on planning, monitoring and control of the transportation stage is reviewed. The current practice in management of the transportation stage of the construction material procurement process and perception of industry practitioners about the importance of considering material transportation in project planning is evaluated using the results of a limited systematic survey. In addition, the importance of transportation in the procurement of construction materials is studied by considering the actual data on shipment of construction materials/components in two industrial projects.

2 Literature Review

2.1 Importance of Transportation in the Supply Chain

The current practice in the construction management field for developing the supply chain is to optimize the overall process by considering the costs trade-offs between three main components of the chain; i.e. transportation, inventory, and production [6]. As a result, this has shaped the dominant mindset in construction industry researches to concentrate on devising cost efficient approaches for logistics and shipment strategies, as one of the three elements. An illuminating example is a part of the research that has been conducted by Irizarry et al. [7] in which Building Information Modelling (BIM) and Geographic Information Systems (GIS) are deployed to manage logistics perspectives of construction material supply chain and then reduce the relevant costs through the trade-off between inbound and outbound transportation costs. Their developed model is also capable of finding the optimum way of transporting material from a supplier to the construction site, in terms of number and time of orders, order quantity, transportation methods, and the associated cost of transportation. These efforts are supposed to be used before the formation of contract between a general contractor and suppliers.

Although the main theme in analysing transportation is founded on cost, there is an interdependent relationship between cost and time. As a result, calculation of transportation time can lead to deciding about optimum transportation options, even in term of cost [8]. On the other hand, measuring time in real situations is simpler and more practical than cost for logistics management. Therefore, it is a reasonable outlook to focus on duration in order to come up with the best option for shipment of goods. By using time as the target for managing movements of purchased materials, it can simply help evaluating how well the companies have planned their shipment and how well they have managed to carry out the plans. In addition, a key to successful improvement of any process is accessibility of adequate information about that process as well as effective management of information [9]. Whereas gathering information about time is relatively easier rather than obtaining and collecting highly sensitive data on cost, using time measures for providing feedback and improving the performance of project material delivery process would have a greater chance to be realized. Therefore, in this research it has been decided to just concentrate on time data of construction material supply chain to assess performance.

2.2 Diversity of Material and Their Lead Time

To address problems associated with the delivery of construction materials, it is vital to comprehend different types of materials and their corresponding supply chain. There are four groups of materials which are named as engineered-to-order (ETO), made-to-order (MTO), assembled-to-order (ATO), and made-to-stock (MTS) products [10]. ETO products are special items that are made from raw material in a manufacturer workshop based on detailed design information and drawings received from engineering companies. Therefore, ETO items are expected to have a relatively long supply chain. MTOs are defined as components that are fabricated (or prefabricated) upon receiving orders from customers without intensive needs to engineering data from other parties. They differ from ATO products as ATOs are assembled from standard available elements. Finally, MTS products are resources only controlled by the in-stock availability of the manufacturer. These four categories of products are usually prioritized based on longevity of their supply chain as ETO, MTO, ATO, and MTS, respectively.

Another common classification of material in the construction industry is based on the lead time. Two main categories of material identified in this classification are critical items and noncritical items. Critical items that are also prominent as long lead items are "those components of a system or piece of equipment for which the times to design and fabricate are the longest" [11]. As expected, noncritical items should be those with shorter supply chains. By comparing these two material categories, it may be reasonable to assume that ETOs and part of MTOs will constitute the majority of the critical items; whereas the rest of MTOs, ATOs, and MTS products may be classified as noncritical items.

Although supply chain of any type of material has its own problems, transportation concerns mainly emerge from delivery of prefabricated components in terms of packing and dimension [12]. The prefabricated components can be put into either MTO or ATO categories of material. There is a lack of rich literature on the transportation phase of supply chain and its importance on the efficiency of the procurement process. This mainly originates from the existing perception in the industry that impact of the transportation stage on plans is insignificant and any problem associated with the transportation of construction materials is in fact a consequence of another problem in the previous steps of the supply chain [13].

2.3 Role of Communication Technology in Managing Delivery of Construction Material

A number of previous studies have focused on logistics to improve transportation of construction items. The dominant methodology to evolve current practices for timely delivery of material appeals to application of communication and information technologies [14]. Monitoring and tracking of deliveries has been determined to be an effective way to ensure timely and efficient handling of delivered material at the jobsite and prevent assembly interruption. For this purpose, using advantages of the Internet was examined in a study conducted by Williamson et al. [15]. To make use of the current achievements in visual monitoring in delivery of construction materials, a system combining BIM and GIS has been established to provide project management team with early warnings on any late arrival of construction components [7].

Lu et al. [16] made a communication network, by integrating Global Positioning System (GPS) with vehicle navigation technology, Bluetooth, and commercial mobile that are connected to a central PC, to position concrete mixer trucks in highly dense urban areas. It was shown that they had better utilization of those vehicles at concreting sites. Radio Frequency Identification technology (RFID) also has been used as a tool to automate custom clearance process resulting in reduction of stoppages and saving time that is normally being lost in import cargos in international air cargo terminals [17].

Although a great deal of effort has been made to improve the efficiency of the supply chain of construction materials through the use of communication technologies; little has been done to investigate the importance of the transportation stage and developing methods to improve the efficiency of the transportation stage.

2.4 Delivery Strategy

In international trades, transport of goods and material between seller and buyer requires a number of decisions to be made. Two important decisions that may influence the cost and the speed of the shipment are mode of transport and terms of delivery. While mode of transport is usually chosen after a trade-off between cost and duration of delivery, finalizing terms of delivery depends on risk-taking attitude and power of the parties involved [18]. In other words, assuming availability of all transportation options, the decision to use train, truck, vessel, and airplane is generally conformed to the limitation of time and cost. In statement of trade terms, the location where ownership is transferred, as well as arrangements for payment of any cost associated with delivery of items are clarified and it is a likely approach that each party would try to transfer all the risks and responsibility of paying all costs to the other party. INCOTERMS that are defined and published by the International Chamber of Commerce are put into action to minimize the probability of misunderstandings in such deals. INCOTERMS are a set of three-letter standard trade terms that are classified into four groups and distinguished by increasing obligations and risk assumed by the seller. In the E terms, seller is just responsible to make goods available at its own facility while in F terms his obligation is extended to delivery of the goods to the carrier appointed by the buyer. In group of C and D, however, seller will accept an increasing responsibility toward delivery of goods to the place of destination [19].

3 Current Practices in Planning Delivery of Construction Material, Outcomes of a Qualitative Survey

Twelve construction industry professionals with characteristics summarized in Table 1 were surveyed about their experience in planning logistics and transportation of components between suppliers' workshop and construction site. To increase reliability of the results, interviewees with different backgrounds in terms of organization, industry, and functional role were selected.

Table 1. Characteristics of interviewees

Characteristics	Owner	Contractor	Consultant
Experience			
12-20	0	2	1
20-25	2	3	1
Above 25	1	1	1
Education			
B.Sc.	1	6	1
M.Sc.	2	0	2
Industry			
Oil/Energy	1	3	1
Petrochemical	1	2	2
Mineral	1	1	0
Functional Role			
Project Management	1	2	2
Procurement	1	2	0
Planning	1	2	1

They were from energy, petrochemical, or mineral processing sectors in which supply of material is a significant part of executing a project. Each of them possessed responsibilities for managing the delivery of material, either in owner, contractor, or consultant companies. Survey participants were asked to judge mainly by considering only the items which require international trips as a part of their delivery process. The outcomes of interviews are discussed in the following.

3.1 Significance of Transportation in Supply of Material

The results of the survey performed as a part of this study showed that transportation plays a significant role in the procurement process under following circumstances:

Reducing Cost of Inventory: The cost of inventory usually accounts for a considerable portion of the material handling costs. Therefore, reducing the costs of inventory through using more sophisticated material management approaches such as the just-in-time inventory approach is commonly applied in some industries to reduce the overall material handling costs. Successful implementation of such methods to reduce the inventory duration and costs requires precise planning of transportation as the last step before storing material.

Space Limitation: Space limitations on the job site is another common problem faced by project managers in many construction projects. When facing difficulties in placing commodities of project on the job-site, project managers try to postpone the delivery of materials until they are actually needed. In such cases, keeping track of the delivery of goods to the site and thus management of transportation gain considerable importance. This situation may be observed in offshore projects, projects implemented in urban areas, or in the middle of some congestive construction projects.

Propagation of Delay: Transportation will be brought under special considerations, when the previous stages in the supply chain of material are delayed and the float time has elapsed. In such cases, alternative modes of transport are usually evaluated to accelerate the delivery timing.

Mandatory Completion Date: When there is a tight schedule for the whole project, like projects with a fixed finish date, all project tasks including transportation activities should be scheduled carefully.

3.2 Planning the Delivery

The planning of delivery is conducted to develop delivery schedules, terms of delivery and the mode of transport. The results of the survey conducted to investigate the current practice in planning of deliveries are summarized in the following:

Scheduling: To detail material delivery milestones, pro-rata allocation of shipment time based on the overall supply chain duration is usually performed; i.e. a longer manufacturing time, more time is needed to transport it!

Term of Delivery: Trade terms for delivery of materials between supplier and contractors are set while trying to transfer risks to the suppliers. This is because there is a common perception among contractors that suppliers are generally more experienced in material movement and handling.

Mode of Delivery: In cases where contractors are kept responsible for transportation, the major deciding factor for selecting the mode of delivery is the cost at the time of planning. Decision making about the mode of delivery is usually performed based on personal judgments of logistics team about the costs and a detailed analysis is seldom performed. Unforeseen conditions sometimes force the management to change the delivery mode.

3.3 Special Issues in Managing Delivery of Components

Short-Term Nature of Dealing with Suppliers: One-off and temporary relationships between construction firms and suppliers were identified by the survey participants as the root cause of poor management of the delivery process.

Traffic Management: Obtaining the required permits from road and transportation authorities is in some cases a time consuming process. It takes endeavours to precisely study the current road limitations and detail allowable load and dimensions of the consignments in conjunction with the considerations for the existing traffic.

The results of the survey show that this is one of the common difficulties faced when projects require the shipment of heavy and bulky items fabricated offsite. The survey highlights the necessity of in-advance definition of strategies for ordering large and heavy equipment and components.

4 Case Studies

The transportation stage of construction materials in two actual industrial projects were studied to investigate the current practice in planning of transportation in procurement of construction materials. The projects were selected intentionally from oil-refinery construction projects which require usually the procurement of a considerable amount of materials and components fabricated offsite. The scope of the first project was revamping and expansion of an existing oil refinery, while the scope of the second project was construction of a new gas refinery. Both projects are located in the Middle East and are currently in the construction phase by different contractors. Components required in both projects are procured from a series of international suppliers.

Table 2. Number of purchase orders with various characteristics arrived at the construction sites

Characteristics of Orders	Material Category				
	Structural	Mechanical	Piping	Instrument	Electrical
Weight (ton)					
Light (<1)	7	1	7	1	2
Medium (>1, < 10)	6	5	22	4	5
Heavy (>10 , <100)	9	14	15	3	4
Super heavy (>100)	21	12	11	0	0
Dimension (m^3)					
Small (<1)	9	3	6	1	0
Medium (>1, < 10)	6	5	25	5	7
Large (>10 , <100)	12	13	14	2	3
Super large (>100)	16	11	10	0	1
Term of Delivery					
C	33	21	29	7	8
D	4	3	8	1	1
E	2	2	8	0	0
F	4	6	10	0	2

These projects require the procurement of more than 3500 diverse items which can be grouped into structural, mechanical, piping, instrumentation, and electrical groups. The total number of purchase orders made and delivered to the construction sites by the time of this study is 149. Table 2 summarizes the characteristics of the orders in terms of weight, dimension, and trade condition of delivery.

In compliance with practitioners' point of view, investigation of initial time schedules revealed that the planned transportation duration, from vendor's shop to the final destination, has been estimated initially as a proportion of the overall supply chain length. The ratio of planned transportation duration to the total procurement duration was found to vary from 10 to 20% for the majority of items. In this study, the overall procurement duration is considered as the time period between placing a purchase order and its arrival at the construction site.

Table 2 shows that 66% and 11% of all items are categorized respectively under C and D terms of delivery. This originates from the expected risk-aversion tendency of contractors persuading them to transfer as much risks as possible to sellers.

The data available on material handling durations demonstrates considerable deviations from the planned durations for transportation activities. Figure 1 examines the relationship between the duration of transportation and the total supply chain duration for various items delivered. In this Figure, items have been divided into ETO, MTO, ATO, and MTS categories described earlier. As shown, the ratio between duration of transportation and total supply chain duration varies from 2 to 70%. This clearly contradicts the planning strategy adopted in these projects which assumes a directly proportional relationship between the duration of transportation stage and the total supply chain duration. The results presented in Figure 1 show that this commonly used rule of thumb for estimating the duration of transportation is invalid for about 60% of the items investigated in this study and therefore highlight the need for a more reliable method for planning the transportation stage. It may be concluded that the period of shipping should be estimated by identifying the parameters affecting the transportation stage and regardless of the duration of other stages of supply chain. Therefore, investigating the factors affecting the duration of transportation and developing methods for quantifying the impact of each factor are highly appealing.

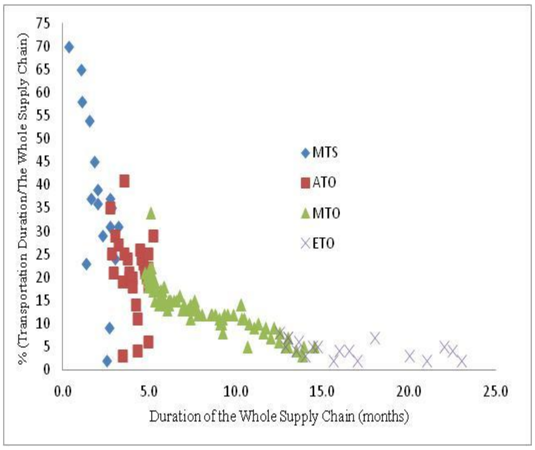

Figure 1. Actual duration of transportation vs. total supply chain length for different categories of construction material

Mean values and standard deviations (STDEV) for delivery period and average delay of items in different material categories are compared in Table 3. As shown, material categories with shorter lead time show generally higher deviations from the planned transportation durations than items with longer lead times. On the other hand, as shown in Figure 1, for materials with relatively shorter lead times, transportation may be considered as the most dominant phase of the supply chain in terms of duration, accounting for more than 40% of the total supply chain duration in some cases.

Table 3. Delivery duration for different categories of material and its deviation from planned value

Material Category	Actual duration of Transportation (Days)		Delay (Days)	
	Mean	STDEV	Mean	STDEV
ETO	26.49	1.28	1.20	0.85
MTO	29.18	5.71	5.84	6.67
ATO	25.33	9.63	10.31	6.02
MTS	22.31	7.84	12.7	4.91

In other words, whereas travel time for different types of components from a specific destination will relatively remain the same, the effect of probable transportation delay on the overall supply duration seems to increase with a decrease in the lead time of items. Therefore, the results suggest that despite the common perception, the effects of material transportation on material procurement delays are more significant for off-the-shelf or MTS components and therefore, a greater deal of attention should be paid to planning the transportation of the items in this material category.

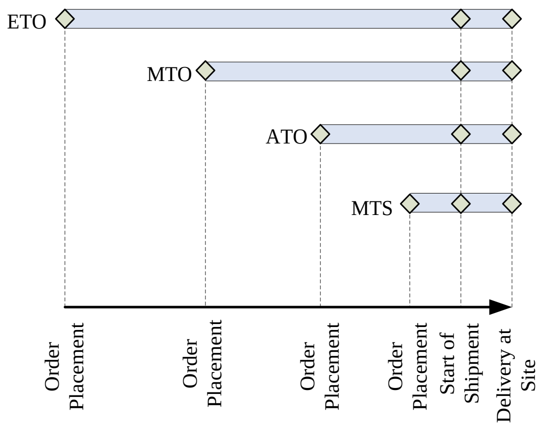

Figure 2. Transportation duration versus overall procurement duration

This fact is highlighted in Figure2 which indicates a schematic view of timescale for supplying different categories of material (from a specific origin) and draw attention to importance of precise planning for delivery of items with shorter lead time. Among different categories of construction material, any delay in ETO and MTS types may directly push back completion date of the project. This is because ETOs are needed to perform critical activities and MTSs are general bulk materials that are consumed in both critical and non-critical paths of the project. Hence, this fact will intensify significance of taking proper strategies for planning delivery of MTS components.

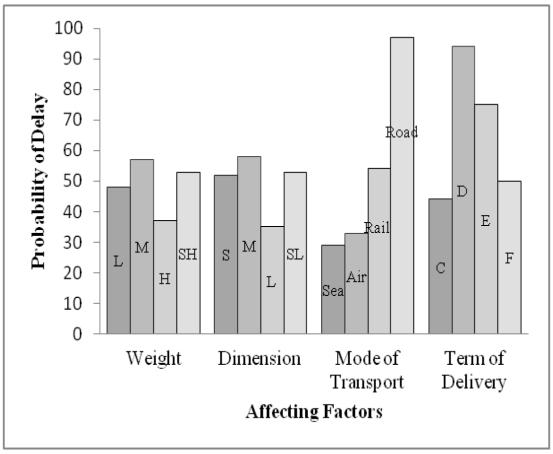

Figure 3. Effect of shipment variables on probability of delay in transportation period (Light: L, M: Medium, H: Heavy, SH: Super heavy, S: Small, L: Large, SL: Super Large)

The shipment data of the case projects were also used to investigate the effect of weight, dimension, mode of transport, and term of delivery on probability of delay. Figure 3 shows the variation in the likelihood of time overrun in transportation of materials to the construction site with variation in the aforementioned variables. As it can be seen, the results indicate that despite the common perception in the industry, an increase in weight and/or dimension of consignments is not necessarily accompanied with an increase on the likelihood of delay in the transportation phase. Variations in weight and dimension of items seem to have relatively similar effects on the likelihood of delay although the amount of occurred delay is absolutely different for each group (Table 4).

Figure 3 also shows that ensuring timely delivery of materials and preventing unwanted elongations requires a holistic approach in selecting the mode of transportation and setting the terms of trade. As shown, sea and air seem to be more reliable modes of transportation than road and rail transportation. However, this reliability may be negatively affected by enforcing D and E terms in relationship with suppliers. The higher possibility of delay in road transportation could be attributed to the intervention of external factors like design limitations of roads, traffic management policies and restricted access for heavy vehicles, and accidents which are not fully controlled by the project team. Enforcing D and E terms means that one party bears the majority of, if not all, the risks associated with the delivery of items which could be resulted in boosting risk of delay, because that party will accept responsibility of shipment even in the region of the counterpart. In general, the results of this case study suggest that realistic transportation plans cannot be achieved by considering the travelling distance as the only variable. Besides distance, the dimensions and weight of item, mode of transport and terms of delivery should be taken into account when planning the transportation activities.

Table 4. Range of delay in shipment of orders classified based on combination of weight and dimension

Density Index	Weight	Dimension	No. Of Orders	Average Delay
1	Light	Small	14	5.41
2	Light Medium	Medium Small	6	6.4
3	Light Light Heavy Super Heavy	Large Super Large Small Small	2	6.75
4	Medium	Medium	21	6.17
5	Heavy Medium	Medium Large	27	10.03
6	Super Heavy Medium Heavy	Medium Super Large Large	28	9.35
7	Heavy Super Heavy	Super Large Large	32	4.95
8	Super Heavy	Super Large	19	3.78

As shown in Table 4, a density index (based on the range of weight and dimensions of items) was defined and introduced to evaluate the effects of various combinations of item's weight and size on delay. It shows that in the case projects presented here, the items with density index of 5 experienced the maximum delay. Items with density index of 5 normally include packages of large numbers of different small items such as packages of thousands of piping accessories and fittings. One probable reason for the higher delay experienced by such items is the typically long and labour intensive custom clearance process required. The second highest delay corresponds to items with density index of 6. According to the project database, majority of items in this category have irregular shapes and centre of gravity which are likely to experience delays during loading and unloading. Table 4 moreover shows that items with density index of 7 and 8 showed minimum delays. Items in this category were mostly huge equipment in cubic or cylindrical packs which require usually less inspection in customs and experience less difficulties in loading and unloading.

5 Conclusion

Construction contractors are permanently concerned with improving supply chain of material. In this way, advancement in logistics management has been proven to be an important ingredient for success. Although reducing costs of logistics can benefit involved parties, it should not direct them to the pitfall of overlooking time management in movement of material. Moreover, time is a readily available measure than can be used as an indication of performance in cost management. Consequently, it is essential to spend efforts on developing cautious time schedule for transportation of construction material and carry out this plan.

Current practices in delivery of material to the construction sites are mainly in connection with movement of special items on local roads and squeezing schedule of transportation to reduce effects of delays during prior stages. While such practices are accredited, still modification of the mind-set in estimating duration of shipping is required. In addition, dimension and weight of orders as well as mode of transportation are effective factors in calculation of delivery length. Parties also should be aware that transferring risks through trade terms may create a new risk causing late arrival of their consignments.

Transportation is an issue that calls for approaches which are not normally influenced by duration of their engineering phase or fabrication at factories. Therefore, considering factors like traffic management, loading and unloading problems, custom clearance issues, and cooperative approaches between buyer and seller is vital to realistic estimation of delivery time and would help the project team to successfully manage this milestone. Nonetheless, it may have significant contribution in time management for supply of material that have short lead time.

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