REDUCING MATERIAL MANAGEMENT COSTS THROUGH LATERAL TRANSSHIPMENT

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ABSTRACT

Materials required for precast fabrication are dissimilar to those cast at construction sites. Fabricators who lack materials must wait until specific suppliers deliver the required materials. Transshipping material from lateral suppliers may be beneficial for reducing waiting time and material management cost. The objective of this study is to reduce total material management costs in the supply chain system through the most advantageous transshipment strategies. A material supply chain framework that enables fabricators to implement lateral transshipment is first proposed. Transshipment strategies are then formulated into a mathematical model. The most advantageous transshipment strategies are analyzed using computer simulation. Diverse order lead times, demands, transportation costs, and shortage costs are simulated to approximate operational conditions encountered in supply chain systems. Through various experiments, the most advantageous strategy for precast fabrication industry could be found. In addition, rules are developed based on simulation results to enhance transshipment decision making.

KEYWORDS

Precast fabrication, supply chain management, material transhipment, computer simulation.

INTRODUCTION

Supply chain management is becoming more and more important within recent construction management research and practices (Khalfan et al. 2005). Precast fabricators strive for business success by delivering products on time. This goal cannot be achieved without flexible and sufficient material supply (Ko and Ballard 2004). Precast fabricators make material plans primarily depending on experience (Blakemore and Konda 2010). This unsystematic manner in which plans are made depends on the subjective recognition that material requirements cannot be appropriately targeted for production (Vollmann et al. 2004, Arbulu et al. 2005). Material supply has become one of the key issues to enhance company competitiveness (Ulubeylia 2010, O'Brien et al. 2002).

Previous researches have proven material sharing to be a promising way to provide fabricators with a flexible material supply, especially for industries that manufacture with special materials (Lee et al. 2007, Björnfot and Torjussen 2012). However, the transshipment models developed by the current studies ignored transshipment lead time and transportation costs, which is inappropriate for an

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industry with long lead time and high transportation costs, such as the precast concrete industry. This research hypothesizes that ignoring transshipment lead time and transportation costs is inappropriate for precast concrete industry with long lead time and high transportation costs. In addition, material sharing is assumed a promising way to provide fabricators with a flexible material supply.

The objective of this study is to reduce total material management costs in the supply chain system using a lateral transshipment strategy. The most advantageous strategy is analyzed using computer simulations. The material transshipment strategies analyzed in this study were established by considering material order lead time and the retailer's future demand. The most advantageous strategy is determined according to total supply chain system cost.

BACKGROUND INFORMATION

INVENTORY CONTROL METHODS

The method that reviews inventory affects the inventory level measurement accuracy. Inventory reviewing methods include two categories: continuous review and periodic review, where (s, Q) and (s, S) are continuous reviews and (R, S) and (R, s, S) are periodic reviews. The following explains these four reviewing methods (Axsäter 2006, Silver et al. 1998):

1. (s, Q) method

This method reorders Q amount when the inventory level drops to reorder point s. The advantage of using this method is that it is simple and easy to use. However, because this method is inflexible, it fails to provide sufficient material once the requirement grows larger than Q. This method is frequently used when the demand for a downstream supplier can be predicted.

2. (s, S) method

When the inventory level meets the reorder point s, the inventory is filled with amount Q to reach level S (i.e. S = s + Q). The advantage of using this method is that the total cost of managing the inventory is more economical than using (s, Q). However, the calculation process for this method is more complex than using (s, Q). Because ordering Q amount varies, an abundance or shortage occurs when the fabricator inaccurately predicts future demand.

3. (R, S) method

The (R, S) reorders Q amount to reach inventory level S at every time period R. Precast fabricators frequently use this method when they have specific suppliers. Although this method can be used to track demand trends corresponding with time, the order cost may be increased if R is short. Inventory shortages may also occur before reorder.

4. (R, s, S) method

This method combines (s, S) and (R, S) methods, which reviews the inventory level at every time period R. When the inventory level drops to s, fabricators reorder Q to reach level S. Using this method, fabricators can benefit from pre-evaluate the reorder amount according to future requirements. The total cost for using this method is relatively low, if accurately evaluating future requirements.

LATERAL TRANSSHIPMENT

Lateral transshipment (also known as material sharing) is a concept that reduces system variability by transshipping materials from manufacturers that have sufficient supplies to others starved for materials. The benefits of adopting lateral transshipment include reducing average inventory level, reducing inventory cost, and reducing safety stock level. The following explains recent investigations on material lateral transshipment:

1. Axsäter (1990b) investigated a two-tier inventory problem between multiple retailers using a central warehouse. Axsäter assumed a fixed order lead time and the demand obeys a Poisson distribution. That study also constrained lateral transshipment by executing from a central warehouse to a retailer. In the same year, another report (Axsäter 1990a) extended the two-tier inventory problem to three layers, transshipping materials between retailers. The primary objective of these studies was to reduce material shortages.

2. Tagaras (1999) regarded that emergency orders require extra cost and time. Tagaras proposed a pooling policy between retailers. Retailers could reduce shortage and inventory costs through sharing inventory resources. Tagaras' risk pooling assumed all retailers used a periodic ordering system. Since that model had not considered emergency orders, retailers could only ask for help from other retailers when they lacked materials. Other retailers transshipped extra inventory to those starved for materials. This policy is called lateral transshipment. Using lateral transshipment, holding costs for retailers with extra inventory and shortage costs for those lacking inventory can be reduced. This concept also reduces emergency order costs. However, Tagaras (1999) did not consider order lead time and the cost for implementing lateral transshipment.

3. Banerjee et al. (2003) concluded that adopting lateral transshipment could dramatically reduce material shortage risk. Those authors felt that placing emergency orders consumed more cost and time. Their transshipment assumed that retailer demand obeyed a normal distribution. The model developed by Banerjee et al. (2003) used a periodic order system. They analyzed the uncertainty in the supply chain with low demand and high demand using computer simulation techniques. Their research finding was consistent with previous studies i.e., lateral transshipment reduces holding, inventory costs, and material shortage risks. However, their study did not consider future requirements after transshipment, which means that inventory shortage may occur after lateral transshipment. As a result, cost, frequency, and transshipment time may be increased using their model.

RESEARCH METHODOLOGY

In order to systematically achieve research objectives, research methodology is elaborated, summarized in Figure 1. Difficulties encountered in precast fabrication are first surveyed. Potential approaches for overcoming these difficulties are investigated. Supply chain management, inventory control methods, and lateral transshipment theories are reviewed in this step. A supply chain system is then developed to drive the material transshipment. In this activity, uncertain demand of precast fabricator is established. A review policy is determined to monitor inventory lever. Lateral transshipment can be launched if it conforms to transshipment policy. Finally, refilling method is analyzed when transshipping materials.

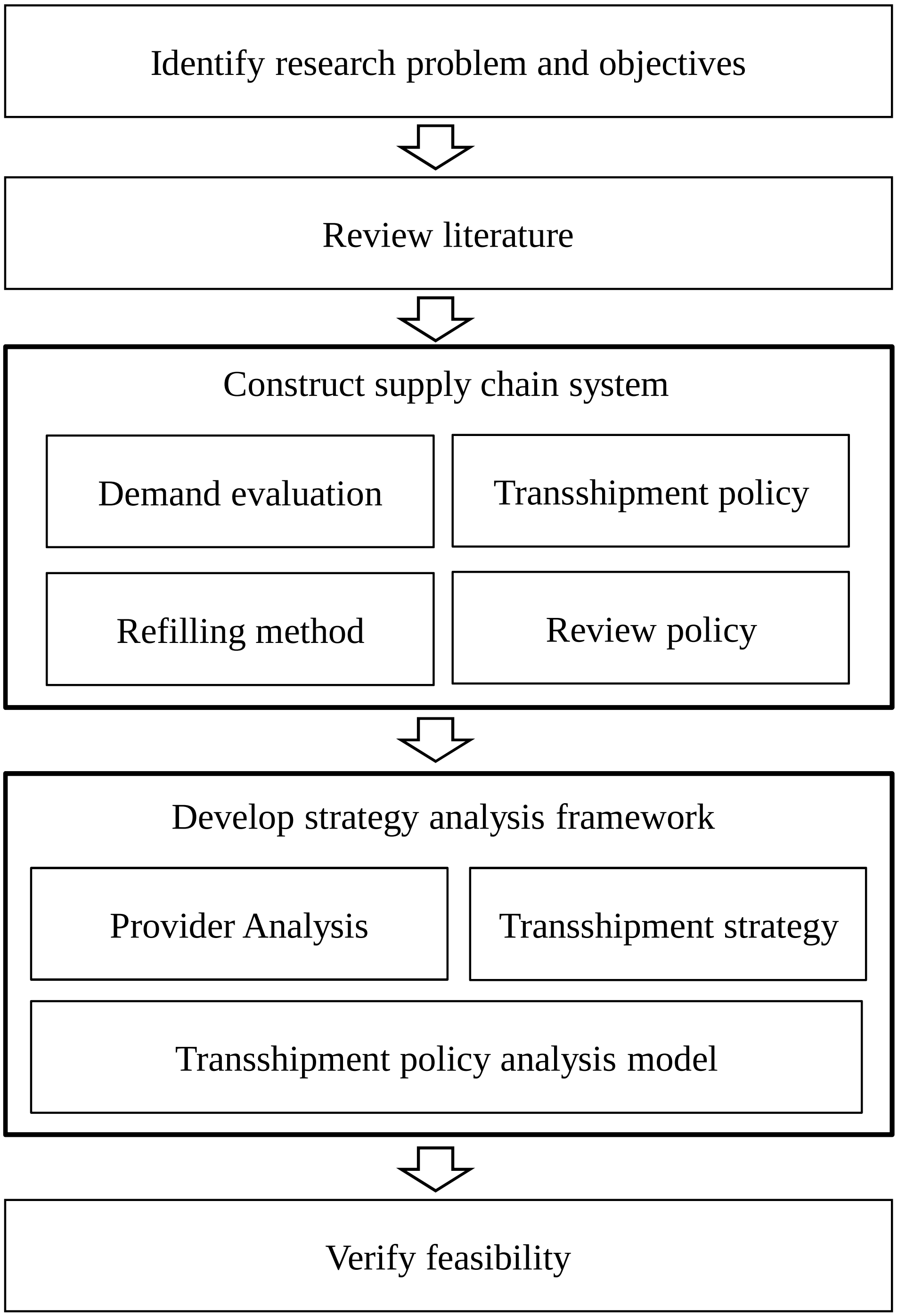

Figure 1: Research Flow (Adopted from Ko 2012)

SUPPLY CHAIN SYSTEM

To enable fabricators to implement material transshipment, this study constructs a supply chain framework. The framework consists of a central warehouse with multiple fabricators, explained as follows:

1. Uncertain demand evaluation

This evaluation assumes that the precast fabricator's demand obeys a normal distribution. Only positive demands are considered in this study. Negative demand values are replaced by 0 in the analysis process.

2. Review policy

This system adopts a periodic review to monitor inventory level and chooses a method for reducing review cost due to repetitive monitoring.

3. Transshipment policy

This study defines factories with sufficient inventory for others starved for materials as providers and defines manufacturers starved for materials as receivers. Lateral transshipment will not be executed if receivers can replenish their inventory in the next day.

4. Refilling method

This study uses an order-up-to method to refill stocks.

STRATEGY ANALYSIS FRAMEWORK

PROVIDER ANALYSIS

The transshipment strategy analysis process is composed of two stages. The first stage critiques whether a manufacturer has sufficient material for others. If any providers exist, appropriate transshipment strategies are analyzed in the second stage. Whether a manufacturer is qualified as a provider is estimated by its demand from the current time point to the next review time point. If the current inventory is sufficient for that interval, the retailer is qualified. Otherwise, providers may become receivers after transshipment.

TRANSSHIPMENT STRATEGY

Lateral transshipment uses shipping materials from fabricators (providers) with sufficient materials to those (receivers) eager for materials. However, materials could be transshipped in many ways, such as randomly selecting providers and receivers, or transshipping materials from the most sufficiency providers to those with the most shortage. Determining an appropriate strategy is crucial to successfully implementing lateral transshipment. Axsäter (1990a, 1990b) and Banerjee et al. (2003) proposed priorities for emergency transshipment. Unfortunately, their strategies ignored future demands for the providers themselves. As a result, the providers may fall victim to material shortage after shipment. This study adopts the transshipment strategies proposed by Axsäter (1990a, 1990b), Banerjee et al. (2003), and Li (2005) by considering future demands and order lead times. Six transhipment strategies are considered in this study:

1) No Lateral shipments (NLS),
2) Random policy (RA),
3) make lateral transshipments based on availability priority policy I (TBAPR I),
4) make lateral transshipments based on availability priority policy II (TBAPR II),
5) make lateral transshipments using the inventory equalization policy (TIE), and
6) moving average policy (MA).

EXPERIMENTS

To verify feasibility of the developed transshipment policy analysis model, this research used precast rebar cases to test the model. The specifications for rebar material used in precast fabrication are dissimilar to those cast on sites. As a result, reordering lead time is longer than that for the general rebar used at construction sites. The input data were generated from a hypothetical scenario to create a comprehensive data set. Therefore, the developed transshipment model can be thoroughly tested. This experiment considered four factors i.e. demand variability, multi-manufacturer systems, order lead time, and costs to approximate real situations. Total cost in this study (noted as TC) includes transportation (TRC), holding (HC), and shortage costs (SC), represented in Eq. (1):

$$TC = \sum_{i=1}^{m} \sum_{j=1, j\neq i}^{m} TRC_{ij} + \sum_{i=1}^{m} HC_i + \sum_{i=1}^{m} SC_i \tag{1}$$

where i and j are different fabricators in the supply chain system (Ko 2012). In the real-world scenario, the data for the transportation (TRC) cost can be retrieved from the cooperated logistic. Holding (HC) cost can be calculated according to the storage yard expenditure. Regarding shortage costs (SC), it is stated in the contract about the penalty of late delivery. In practice, holding cost is relatively less than shortage and transportation costs. As a result, holding cost was fixed as one per unit in this study. Five combinations of the shortage and transportation costs were used to experiment with the impacts of shortage and transportation costs together with the holding cost. These combinations provide opportunities with relatively small and relatively large shortage and/or transportation costs. The simulation implemented each multiple manufacturer system 300 times in 20-day periodic reviews. Table 1 shows the total costs average for the three manufacturers. In the table, the strategy with the minimum unit cost could be regarded as the best transshipment strategy. Simulation column denotes the combination of different distributions for *TRC*, *HC*, and *SC*.

Four operational rules are developed while implementing simulation experiments. These rules are summarized based on simulation experience. These four rules may provide an easy-to-use procedure for precast fabricators to make transshipment decision when lack materials:

Rule 1: If transshipment lead time is longer than reorder lead time, lateral transshipment is not required.

Rule 2: Providers should consider future demand and only transship extra materials.

Rule 3: Providers with the most sufficiency ship materials to those with the most shortage to immediately replenish reserves.

Rule 4: Transportation, holding, and shortage costs have a crucial impact on transshipment decision.

Table 1: Total Cost for the Three Retailers System

Simulation	Transshipment strategy					
	NLS	RA	TBAPRI	TIE	TBAPRII	MA
1-1	383703.40	383272.24	382912.77	383233.92	383138.25	383091.10
1-2	387890.01	386974.58	386265.39	386935.88	386750.63	386619.69
1-3	387692.35	386820.49	386184.33	386781.81	386535.11	386452.97
1-4	459879.64	450107.24	441261.22	450062.22	445403.58	445148.41
1-5	401032.18	401716.35	403068.33	401576.22	401767.24	401829.54
2-1	398556.50	398305.69	398140.12	398265.86	398231.70	398207.73
2-2	401881.45	401326.37	401002.71	401286.24	401237.15	401229.82
2-3	401851.63	401410.26	401114.21	401370.12	401345.48	401308.92
2-4	437221.24	432458.02	429964.97	432414.78	431441.73	430907.81
2-5	407076.88	407416.58	408026.34	407375.83	407701.69	407923.01
3-1	387032.57	386667.77	386447.51	386589.10	386556.21	386474.75
3-2	389539.54	388867.31	388362.81	388728.42	388615.42	388419.55
3-3	390015.13	389540.75	389008.21	389421.79	389239.37	389166.69
3-4	450903.10	445015.44	438894.02	443370.93	442529.01	440130.88
3-5	401097.43	401171.29	402263.51	401131.17	401528.69	401934.01
4-1	390474.90	388593.06	387690.80	388554.20	388496.32	388370.74
4-2	399418.17	395887.97	393491.29	395848.38	395520.64	395436.73
4-3	400056.64	397039.64	394619.07	396999.93	396599.79	396140.55
4-4	567653.40	535974.35	508950.09	535920.75	524879.26	521369.65
4-5	424469.02	432574.42	433438.78	428531.76	429067.76	431219.78

CONCLUSIONS

This study developed a framework for applying lateral transshipment to precast construction. A central warehouse with multiple precast fabricators was simulated in this study. To eliminate imminent shortage, the developed framework transships materials from fabricators with sufficient supplies to others starved for materials. This research analyzed six strategies considering uncertain demand, diverse order lead time, and the scale of supply chain systems. Simulation results show that the TBAPR I strategy induces minimum inventory and material shortage costs when implementing lateral transshipment. Previous studies in multi-echelon supply chains have highlighted that lateral transshipment reduces both inventory and shortage costs. However, this study found that lateral transshipment is not always beneficial in the construction industry where it is more appropriate for fabricators located in nearby areas. The simulation results also showed that longer order lead time increases total cost. For a larger multiple manufacture supply chain system, a greater number of fabricators participating in the corporate system enhances the amount of material shortages that can be reduced. Four operational rules developed based on these simulation results may provide precast fabricators with a quick procedure to make transshipment decisions without complex computer simulations.

ACKNOWLEDGMENTS

This research was funded by grants NSC 94-2218-E-212-011, NSC 95-2221-E-212-051, NSC 96-2221-E-020-030, and NSC 97-2221-E-020-036- MY2 from the National Science Council (Taiwan), whose support is gratefully acknowledged. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the author and do not reflect the views of the National Science Council. The writer would also like to thank the investigated precast fabricator for supporting this study. Special thanks are due to student Yu-Dian Li for data analysis, equations formulation, and simulation programming.

REFERENCES

Arbulu, R., Koerckel, A., and Espana, F. (2005). "Linking Production-level Workflow with Materials Supply" *Proceedings of the 13th International Group for Lean Construction Conference*, 199-206.

Axsäter, S. (1990a). "Modeling emergency lateral transshipments in inventory system." *Management Science*, 36 1329-1338.

Axsäter, S. (1990b). "Simple solution procedures for a class of two-echelon inventory problems." *Operations Research*, 38 64-69.

Axsäter, S. (2006). "A simple procedure for determining order quantities under a fill rate constraint and normally distributed lead-time demand." *European Journal of Operational Research*, 174 (1) 480-491.

Banerjee, A., Burton, J., Banerjee, S. (2003). "A simulation study of lateral shipments in single supplier, multiple buyers supply chain networks." *International Journal of Production Economics*, 81 103-114.

Björnfot, A. and Torjussen, L. (2012). "Extent and Effect of Horizontal Supply Chain Collaboration among Construction SME." *Journal of Engineering, Project, and Production Management*, 2(1), 47-55.

Blakemore, F.P. and Konda, T.F. (2010). "Design-Build Replacement of US-90 Bridge over Bay St. Louis, Mississippi." *Transportation Research Record 2201*, 106-112.

Khalfan, M.M.A., Asad, S., and McDermote, P. (2005). "Towards Demand and Supply Management in Construction Industry." *Proceedings of the 13th International Group for Lean Construction Conference*, 109-115.

Ko, C. H. and Ballard, G. (2004). "*Demand variability and fabrication lead time: Descriptive research*, *phase I.*" Technical Report, University of California at Berkeley, Berkeley, CA.

Ko, C.H. (2012). "Material Transshipment for Precast Fabrication." *Journal of Civil Engineering and Management* (In press).

Lee, Y.H., Jung, J.W., and Jeon, Y.S. (2007). "An effective lateral transshipment policy to improve service level in the supply chain." *International Journal of Production Economics,* 106 (1) 115-126.

Li, Y.D. (2005). "Strategy Analysis of Lateral Transshipment for Material Risk Pooling." MS Thesis, Da-Yeh University, Taiwan (in Chinese).

O'Brien, W.J., London, K., and Vrijhoef, R. (2002). "Construction supply chain modeling: a research review and interdisciplinary research agenda." *Proceedings of the 10th International Group for Lean Construction Conference*, 129-148.

Silver, E.A., Pyke, D.F., Peterson, R. (1998). *Inventory Management and Production Planning and Scheduling*, Third Edition, Wiley Press, New York, NY.

Tagaras, G. (1999). "Pooling in multi-location periodic inventory distribution systems." *Omega the International Journal of Management Science*, 27 (1) 39-59.

Ulubeyli, S., Manisali, E., Kazaz, A. (2010). "Subcontractor selection practices in international construction projects." *Journal of Civil Engineering and Management*, 16 (1) 47-56.

Vollmann, T.E., Berry, W.L., Whybark, D.C., Jacobs, F.R. (2004). *Manufacturing Planning and Control Systems for Supply Chain Management*, Fifth Edition, McGraw-Hill, New York, NY.