A MANAGER'S ROADMAP GUIDE FOR LATERAL TRANS-SHIPMENT IN SUPPLY CHAIN INVENTORY MANAGEMENT

By implementing the proposed five decision rules for lateral trans-shipment decision support, professional inventory management practitioners can optimize their inventory management systems to determine whether it is more cost effective to trans-ship urgent orders, the size of trans-shipment, the preferred wholesaler and supplier.

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contents

Intro-duction

As competition increases, manufacturers and wholesalers respond by becoming more cost conscious and more responsive to changing market needs.

One supply chain strategy conserves a low inventory level, sufficient simply to fulfil immediate orders. However, a low inventory level is accompanied by a higher risk of stock outages potentially creating the situation where a minimum customer service level is breached leading to sales losses and customer dissatisfaction.

To manage these potentials, manufacturers and wholesalers can increase the flexibility in their inventory systems by adopting a mix of strategies including emergency lateral trans-shipment (LT) from other warehouses at a higher costand simultaneously backordering from their usual suppliers to match the stochastic demand. Decision Rules that support the required decision making process have practical value for inventory management practitioners.

"One supply chain strategy conserves a low inventory level, sufficient simply to fulfil immediate orders."

Inventory management systems seek to minimize total inventory costs while achieving a desired level of customer service. Due to the uncertainty in demand and supply, buffer stocks are deployed to decouple the demand and supply nexus. However, the demand and supply aspects cannot work in isolation, they are inextricably bound up with warehouse design and operation, distribution networks, transportation and other aspects of supply chain management must be integrated to assess which trade-offs should be applied in order to optimize the effectiveness and efficiency of the total supply chain operations.

Where the manufacturer with its regional distribution centres (or all wholesalers) adopt a periodic review policy to replenish inventory from their external suppliers, the unsatisfied demands in the previous period, the current inventory position and the expected demand in the current period are analyzed at the beginning of the next period. Unsatisfied demands in this period will be treated as initial demands or a surplus order will be added to the inventory position of the next period. If the wholesaler does not apply a (R,Q) review policy, its inventory position could drop below R or even approach zero and while holding costs will decrease as a result, there is a strong possibility that its inventory position may enter negative territory; this potentially increases the back-order costs. One possible solution is to apply LT from other wholesalers who have surplus stock to replenish their stock deficiency within a short period of time.

Within the context of LT, a supply chain structure consists of multiple retailers, wholesalers and suppliers, as shown in Figure 1 on the opposite page.

In this scenario, all the warehouses belong to the same company. The black solid lines represent possible trans-shipments among various warehouses within the company. For modeling simplicity, assume only LT between a pair of wholesalers (sender and receiver) Wi and Wj, i not equal j, where i and j = 1, 2, …, total number of warehouses. Similarly, Wi places orders pairwise with a single supplier, instead of multiple suppliers.

Supply chain management models that streamline the flow of goods to optimise total inventory costs, customer service level, total number of stockouts, or other performance criteria

Introduction continued

have been the focus of research for more than three decades. While this research into manufacturer and wholesaler inventory management systems captured complex criteria drawn from diverse theoretical frameworks, these are problematic in real-world practice. There remains a need for simpler and more readily applicable decision rules for the LT decision making process.

The Decision Rule for determining the quantity to be trans-shipped has been examined in previous studies. The Decision Rule is an optimization solution to minimize total inventory costs and achieve a desired level of customer service; it can be repeatedly applied as an heuristic for supply chain management practice. Our study extends previous research to develop decision rules for reactive LT in order to fulfil existing inventory shortages that arise due to urgent demand that cannot be satisfied from the stock on hand. The decision rules determine whether it is more cost effective to trans-ship urgent orders or to backorder all outstanding orders from suppliers, the size of trans-shipment, the favourite wholesaler and the preferred supplier. Further extension covers the preventive extra quantity for LT, which occurs before an inventory shortage emerges.

Previous research studies were populated by highly mathematical probability analysis that are more than likely, quite useless to real-world inventory management practitioners. Our study attempts to overcome this complexity problem. In addition to requiring less complex calculations, the required data can be sourced from previous transaction records, thus enabling adoption of this model by ordinary managers. This new approach builds upon previous scholarly work by proposing what is in effect a more pragmatic decision model for the supply chain environment. This model can be applied to a real context with multiple warehouses of manufacturers/ wholesalers and multiple suppliers with variable lead times. The proposed approach is validated through the practical application of the model in a large case study company.

Data can be sourced from previous transaction records.

Our control process has been designed to identify important decision rules in quantifiable terms for the purpose of achieving operational consistency. The mathematics involved is simple and easy to implement, and the quantitative step-by-step approach supports routine computation of solutions to consistently trigger an appropriate LT response to address the inventory control problems.

The next sections review the relevant literature, the decision rules derived by the proposed mathematical model with application to the trans-shipments decision making process and provide a numerical illustration and roadmap through a case study that has practice values and implications for management.

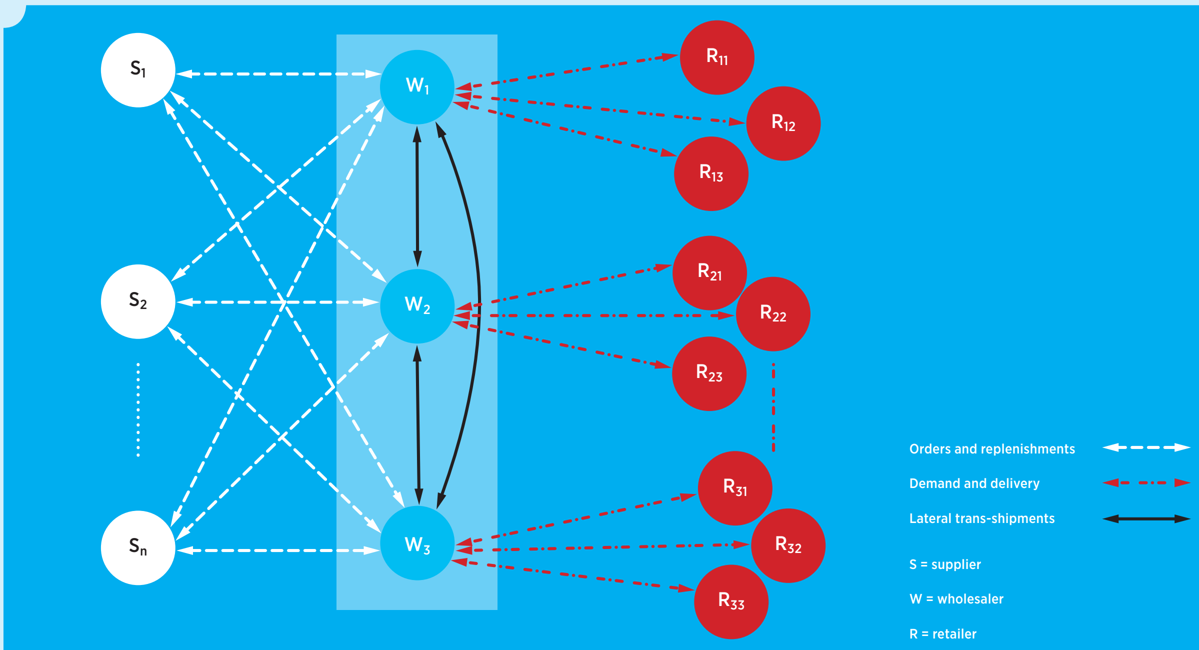

Figure 1: Lateral trans-shipment in a supply chain structure.

CASE STUDY

Our research approach utilizes the LT model to assist practitioners to improve their supply chain systems performance by minimizing total inventory costs that capture stockout as one key cost component. Relevant input indicators have been identified when designing the roadmap for implementing LT. Data collection from the case study company will reveal the baseline and the problems associated with the no LT scenario. Tapping into the literature, expert opinions, and management experiences, we use a comparative study to investigate various interventions and evaluation criteria in order to determine why one intervention is most suitable in improving inventory management. Relevant research results from our study will be summarized in this guideline to facilitate implementation of LT as part of the inventory management system. This practical solution can easily be generalized to other companies to gain similar operational benefits.

This case study company is a major player in the fast moving consumer goods (FMCG) sector, with one national and five regional distribution centers in each of the five major cities in Australia that serve a diverse range of retail stores across wide geographies. Most POS systems in its retail stores have real time access to sales and inventory data, making continuous review policy seem feasible and preferred. However, certain limitations are violating the other conditions for continuous review policy making periodic review policy instead, a necessity. The limitations and constraints at work in this company include a pre-determined schedule, fixed contracts confirmed with customers and shipping companies, simultaneous delivery of a variety of goods, batch update in ERP inventory databases, and inventory decisions that are made as per predefined cycles. Therefore, it is more appropriate for this case study company to use a periodic review policy.

The objective of our research is to measure and improve current inventory management performance by implementing the decision rules of LT so as to minimize the total inventory costs. The key decision is the optimal division of inventory between central warehouse and retail stores. Higher customer service levels can be achieved when more inventories are located at retail stores, this of course carries with it the associated increase in holding and transportation costs. The advantage of positioning more inventories in the national and regional distribution centers is in effect risk pooling that reduces the systems inventory costs across the whole system. This strategy can cause shipment delays however, and these may adversely impact customer service level. Moreover, it is not an easy step to restore subsequent inventory imbalances across the regional distribution centers and retail stores since lateral shipment is not part of the normal replenishment process. Recently, advances in information technology have enhanced the operations of LT. Research studies quantified the potential value of information sharing in a single warehouse/multi-retailer setting, with identical retailers, batch ordering, fixed shipment lead time and a periodic review inventory policy. By comparing the total supply chain costs in with and without information sharing scenarios, the value of information sharing is only 2.2%, which is much less than the benefits from the JIT configuration of shorter lead times and smaller batch sizes, which are approximately 20% each. Therefore, sophisticated communication systems, though beneficial for information sharing within the supply chain, can be over-engineered with inadequate return on investment. Simple and fast communication of inventory and demand status of the regional distribution centers and retail stores should suffice the LT infrastructure with strong potential to achieve performance gains.

> Recently, advances in information technology have enhanced the operations of LT

Generic Decision rules for LT

The earlier literature of analytical and simulation experiments identified several generic decision rules that can easily be comprehended by supply chain practitioners, including:

Rule A

Purchasing, backordering, and holding costs have a crucial impact on LT decision.

Rule B

Backordering is good approximation for lost sales, provided service level is sufficiently high.

Rule C

LT should not be applied if trans-shipment lead time is longer than supplier replenishment lead time.

Rule D

Providers with the most stock surplus trans-ship to those with the greatest shortage.

Rule E

Providers should consider future demand and only transship extra stock surplus.

Rule F

Preventive LT policies are particularly suitable when holding costs are dominant.

Rule G

Reactive LT policies perform better where trans-shipment costs are relatively lower.

However, these simple operational decision rules are in fact a second phase of decision-making; they do not address the prior fundamental LT decisions, e.g. whether to apply LT or not, selection of the preferred wholesaler, optimal size of trans-shipment, selection of the preferred supplier, timing of extra trans-shipment, etc. Furthermore, for large chains with thousands of retail stores, large numbers of policies is not possible in practice. While the complex systems and policies may mathematically generate optimal solutions, the practical advantages of simplifying and categorizing into groups of policies that embody easily implementable decision rules, irrespective of store differences across geographies and products, can be substantial. Our research develops LT decision rules that can be easily comprehended and applied by ordinary managers in their LT decision making process as they attempt to minimize total inventory costs. In the following sections, a detailed step-by-step approach will be outlined for ease of implementation at the practical level of inventory management, where LT plays an important role in minimizing total inventory costs whilst achieving a desired level of customer service.

These simple operational decision rules are in fact a second phase of decision-making

Proposed model-based decision rules for LT

To determine the optimal quantity and timing of LT, the three key cost components of the total inventory costs should be minimized. Input parameters for computing the total inventory costs consist of the following three key cost components:

1. Purchasing costs include all the labour, equipment, and related resources required for order planning, requisition, and monitoring and controlling the progress of order activities, transportation and shipping, receiving, inspection, handling and storage, accounting and auditing costs.
2. Backordering costs incurred when stock on hand is not available to meet customer demand, these include lost sales, estimated loss of future sales and goodwill due to customer dissatisfaction, and contractual penalties of non- or late deliveries. However, because this is largely based on judgement it is generally ignored in inventory costing due to its estimation uncertainty.
3. Holding costs include interest on loans to finance inventory or opportunity costs of inventory investment; storage related costs (rent, provision of facilities, heating, cooling, lighting, security, refrigeration, administrative, handling and storage, transportation); product depreciation, deterioration, spoilage, damages, and obsolescence; insurance and taxes. It amounts to approximately 15% to 30% of the total inventory costs, but is difficult to calculate with any degree of accuracy, and is often underestimated.

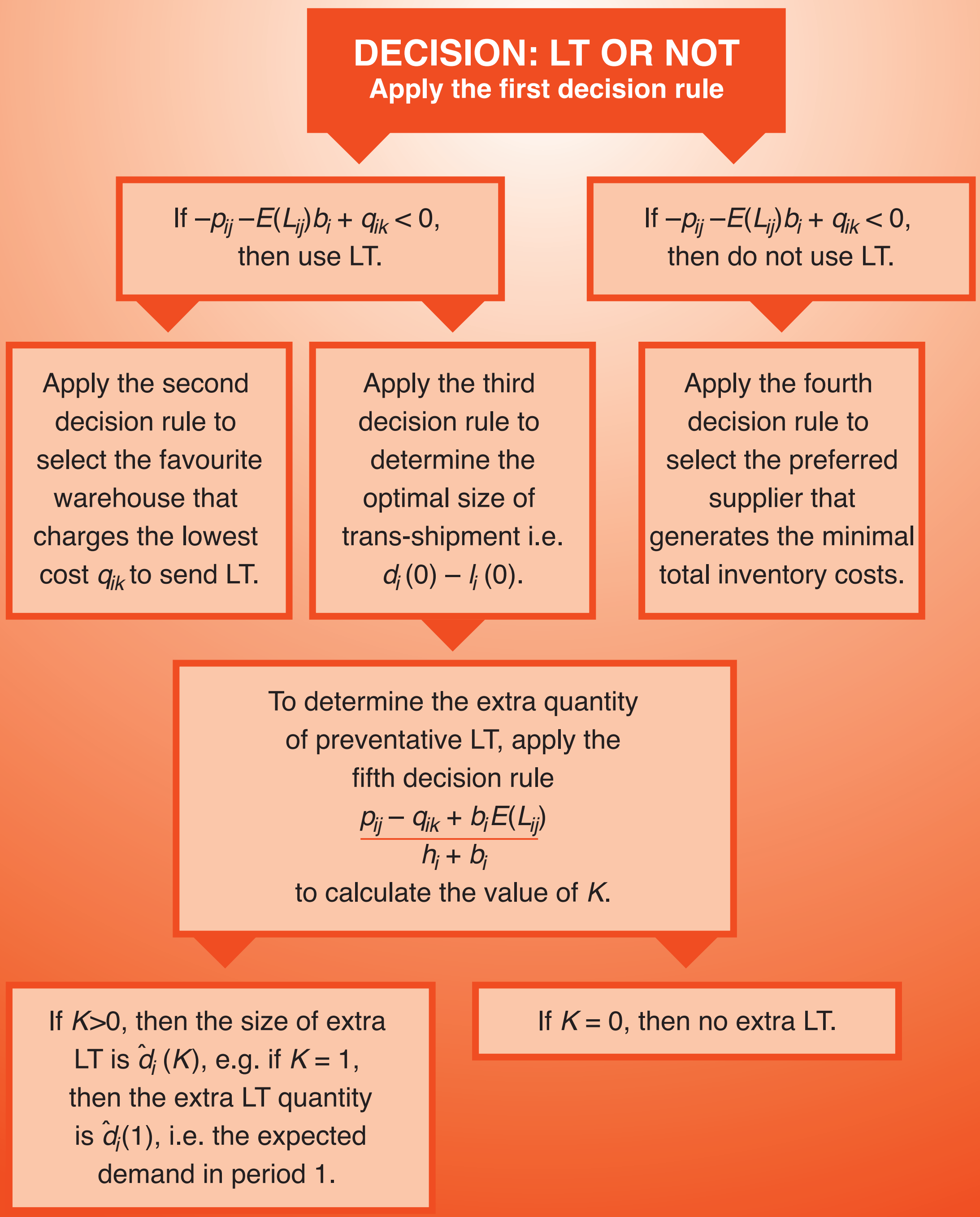

Figure 2: Flow chart for the proposed two-step decision rules

There are five decision rules derived from our model using the analytic method and simulation experiments. Our comparative research study applied these five decision to examine the following set of five trans-shipment strategies:

1. the proposed two-step decision rule
2. no LT
3. LT for only initial outstanding demand
4. LT to satisfy half of the expected demand during the supplier lead time
5. LT to satisfy the total expected demand during the supplier lead time

The input data were compiled from historical corporate database of this case study company, and computed jointly by the operations management and accounting departments. The three key cost components of the total inventory costs were measured as defined above, and examined jointly with various combinations of supplier lead time and trans-shipment costs. To verify feasibility of the proposed LT model, 1,000 simulations of different scenarios have been run. The simulation results confirm the superiority of our proposed two-step LT model. Our proposed two-step decision rules, as shown in Figure 2 above, generate the lowest total inventory costs among these five different trans-shipment strategies.

To implement this proposed LT model, the following five decision rules can serve as an heuristic guide to support LT decision making.

First decision rule: whether to apply LTs or not

The total cost function is linear with respect to the quantity of trans-shipment (x). When the tangent of this linear function $-p_{ij} - E(L_{ij}) b_i + q_{ik}$ is negative, the total inventory costs decrease as the quantity trans-shipped increases.

The five decision rules can serve as an heuristic guide to support LT decision making.

Hence the decision rule for determining whether LT should be applied is,

$-p_{ij} - E(L_{ij})b_i + q_{ik} < 0$ or

$$q_{ik} < p_{ij} + E(L_{ij})b_i \qquad (1)$$

In summary, if the condition of this decision rule, as defined by equation (1), is satisfied, the higher the quantity trans-shipped, the lower the total inventory costs for the wholesaler W_i. Or alternatively, the wholesaler W_i should decide to fulfil the demand by ordering only from the supplier S_{ij} if the above decision rule is not satisfied.

Second decision rule: selection of the preferred wholesaler

As a corollary of the above decision rule that the higher the quantity trans-shipped, the lower the total inventory cost to the wholesaler W_i. This suggests preference should be given to wholesaler W_k that could trans-ship at the lowest cost q_{ik}.

Third decision rule: optimal size of trans-shipment

We only order the initial outstanding demand net of existing inventory at t=0 which is $d_i(0) - I_i(0)$ from another wholesaler due to the higher unit cost of trans-shipment from another wholesaler, as compared with the unit purchasing cost from suppliers. For simplicity of the model, we assume that the preferred sending wholesaler has sufficient stock to deliver the trans-shipment to the receiving wholesaler. Hence the optimum size of the trans-shipment, μ_k is defined as,

$$\mu_k = d_i(0) - I_i(0) \qquad (2)$$

Therefore, the size of the trans-shipment can be either 0 or μ_k in this model. When the decision rule in equation (1) is not satisfied, there will not be any trans-shipment, and the maximum of μ_k is trans-shipped when it is satisfied.

Fourth decision rule: selection of the preferred supplier

The wholesaler W_i can source from any one of its suppliers. The selection decision is derived by the global minimization of the total inventory cost function, with a fixed x ($x \neq 0$) and a known W_k.

Hence, the decision rule is given by the condition that satisfies

$$C_i = \min(C_{i1}, C_{i2}, \dots, C_{ij} \dots, C_{iNi}) \qquad (12)$$

where Ni is the number of suppliers of the wholesaler W_i.

Fifth decision rule: determine the extra quantity of trans-shipment

To determine the extra quantity to be trans-shipped, the time K corresponding to the point of intersection between the two graphs $c_i^T(t)$ and $c_i^S(t)$. K is the maximum integer

less than $\frac{p_{ij} - q_{ik} + b_i E(L_{ij})}{h_i + b_i}$. Therefore, K must be

non-negative and within the range of

$\frac{p_{ij} - q_{ik} + b_i E(L_{ij})}{h_i + b_i} - 1 < K \le \frac{p_{ij} - q_{ik} + b_i E(L_{ij})}{h_i + b_i}$. And the extra quantity trans-shipped is determined by $\delta x = \hat{d}_i(K)$.

A tutorial for the proposed model-based LT decision rules

Based on the above five decision rules, a step-by-step approach is shown in Figure 3 on page 10.

Examples and exercises for the proposed model-based decision rules for LT will be illustrated below.

Step 1: Based on corporate databases, each of the three key cost components, i.e. the purchasing, backordering, and holding costs, as defined in section 3.2, are computed by the joint collaboration of the operations management and accounting departments. An example from this case study company:

q_{ik} = the unit LT cost from the wholesaler W_k to wholesaler W_i = \$5.0

$E(L_{ij})$ = expected lead time of the supplier S_{ij} = 4 days

b_i = unit backordering cost at W_i per unit time = \$2.0

h_i = unit holding cost for the wholesaler W_i per unit time = \$2.2

p_{ij} = the unit selling price by the supplier S_{ij} to the wholesaler W_i = \$2.2

CASE STUDY continued

DECISION: LT OR NOT
Apply the first decision rule

Step 1: Meaure the cost parameters, e.g.
q_{ik} = the unit LT cost from the wholesaler W_k to wholesaler W_i = \$5.0
$E(L_{ij})$ = expected lead time of the supplier S_{ij} = 4 days
b_i = unit backordering cost at W_i per unit time = \$2.0
h_i = unit holding cost for the wholesaler W_i per unit time = \$2.2
p_{ij} = the unit selling price by the supplier S_{ij} to the wholesaler W_i = \$2.2
According to the first decision rule, if $-p_{ij} - E(L_{ij})b_i + q_{ik} < 0$, then use LT. Since $-p_{ij} - E(L_{ij})b_i + q_{ik}$ = -\$2.2 – 4*\$2.0 + \$5.0 = -\$5.2 is negative. Therefore, LT should be implemented in this situation.

If $-p_{ij} - E(L_{ij})b_i + q_{ik} > 0$, then do not use LT.

Step 4: The total inventory costs will be computed for all suppliers. According to fourth decision rule, the preferred supplier generates the minimal total inventory costs.

Step 2: Prepare a list of wholesalers that satisfy the condition $-p_{ij} - E(L_{ij})b_i + q_{ik} < 0$. According to the second decision rule, select the favourite wholesaler W_k that could trans-ship at the lowest cost q_{ik}.

Step 3: The optimal size of the LT is $d_i(0) - I_i(0)$. If $d_i(0)$ is 6,000 units and $I_i(0)$ is zero, then according to the third decision rule, the optimal LT size is 6,000 units.

Step 3: To determine the extra quantity for LT, according to the fifth decision rule, calculate the value of $K = \dfrac{p_{ij} - q_{ik} + b_i E(L_{ij})}{h_i + b_i}$ = (\$2.2 – \$5.0 + 4*\$2.0)/(\$2.0 + \$2.0) = 1.3. The maximum integer less than 1.3 is 1, therefore $K = 1$.

Since $K = 1 > 0$, in this example, therefore the size of extra LT is $\hat{d}_i(K)$, e.g. if $K = 1$, then the optimal extra quantity for LT is $\hat{d}_i(K) = d_i(1)$, i.e. the expected demand for period 1.

If $K = 0$, then no extra LT.

Figure 3: Flow chart for a step-by-step approach roadmap guide

Apply the equation $-p_{ij} - E(L_{ij})b_i + q_{ik}$ = -\$2.2 – 4*\$2.0 + \$5.0 = -\$5.2, which is negative. Therefore, LT should be implemented in this situation, in accordance with the first decision rule.

EXERCISE 1

There are three more scenarios to be considered, with input parameters in the following table. Work out whether LT should be implemented in each scenario. The answers are listed in the Appendix.

Case	1	2	3
q	5	7	6
E(L)	2	2	4
b	2	2	2
h	2	2	2
p	2.2	2.2	2.2

STEP 2

To select the preferred wholesaler, so long as the condition as specified in the equation $-p_{ij} - E(L_{ij})b_i + q_{ik}$ is negative, the wholesaler will be included in the preferred list of wholesalers for consideration, and preference is given to wholesaler W_k that could trans-ship at the lowest cost q_{ik}, in accordance with the second decision rule. For example, in the above exercises, if each case represents an individual wholesaler, then case 1 wholesaler should be the preferred.

STEP 3

The optimal size of the LT is designed to fulfil the initial outstanding demand net of existing inventory at t=0 when the condition for LT is satisfied, i.e. $d_i(0) - I_i(0)$. If $d_i(0)$ is 6,000 units and $I_i(0)$ is zero, then the optimal size of the LT is 6,000 units, in accordance with the third decision rule.

EXAMPLES AND EXERCISES FOR THE PROPOSED MODEL-BASED DECISION RULES FOR LT.

STEP 4

To select the preferred supplier, the total inventory costs will be computed for all the suppliers, and the order will be placed to the supplier that generates the minimal total inventory costs, in accordance with the fourth decision rule.

STEP 5

To determine the optimal timing for preventive extra trans-shipment, the value K is the maximum integer less than $\frac{p_{ij} - q_{ik} + b_i E(L_{ij})}{h_i + b_i}$. Therefore, an example from this case study company:

q_{ik} = the unit LT cost from the wholesaler W_k to wholesaler W_i = \$5.0

$E(L_{ij})$ = expected lead time of the supplier S_{ij} = 4 days

b_i = unit backordering cost at W_i per unit time = \$2.0

h_i = unit holding cost for the wholesaler W_i per unit time = \$2.0

p_{ij} = the unit selling price by the supplier S_{ij} to the wholesaler W_i = \$2.2

Apply the equation $\frac{p_{ij} - q_{ik} + b_i E(L_{ij})}{h_i + b_i}$ = (\$2.2 – \$5.0 + 4*\$2.0)/(\$2.0 + \$2.0) = 1.3. The maximum integer less than 1.3 is 1, therefore, K = 1. And the size of LT is $\hat{d}_i(K) = \hat{d}_i(1)$, i.e. the expected demand for period 1, in accordance with the fifth decision rule.

Exercise 2: There are three more scenarios to be considered, with input parameters in the following table. Work out whether extra quantity for LT is required in each scenario. The answers are listed in the Appendix.

Case	1	2	3
q	5	7	6
E(L)	2	2	4
b	2	2	2
h	2	2	2
p	2.2	2.2	2.2

CONCLUSION

We recommend our proposed model-based LT decision rules to the professional inventory management practitioners on the basis of the evidence of achieving superior inventory management performance and return on implementing LT strategy. By following these step-by-step five decision rules to support the LT decision making process, inventory management practitioners are in an informed position to optimize their inventory management systems to determine whether it is more cost effective to transship urgent orders or to backorder all outstanding orders from suppliers, the size of trans-shipment, the favourite wholesaler, and the preferred supplier. Further coverage of extra quantity for preventive LT, which occurs before an inventory shortage emerges, can also be examined.

Appendix

Answers to Exercise 1

Case	1	2	3
q	5	7	6
E(L)	2	2	4
b	2	2	2
h	2	2	2
p	2.2	2.2	2.2
p + E(L)*b	6.2	6.2	10.2
> or <	>	<	>
q	5	7	6
LT decision rule	LT	no LT	LT

Answers to Exercise 2

Case	1	2	3
q	5	7	6
E(L)	2	2	4
b	2	2	2
h	2	2	2
p	2.2	2.2	2.2
p + E(L)*b – q	1.2	-0.8	4.2
h + b	4	4	4
(p + E(L)*b – q)/(h + b)	0.3	-0.2	1.05
(p + E(L)*b – q)/(h + b)	0.3	-0.2	1.05
K	0	no LT	1
size of LT	d(0)	d(no LT)	d(1)
Extra LT decision rule	no extra LT	no extra LT	extra LT

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