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Classification of Postponement Strategies and Performance Metrics Framework

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Abstract

Postponement strategy is an efficient solution to combat against runaway costs due to quick response to customer order, increasing product variation and demand for product customization. Over time, the scope and application of postponement has expanded to various aspects in the supply chain. This paper surveys various types of postponement and classifies them based on the view of reconfiguration of the supply chain network, which contains form, time and place postponement. It also proposes a performance metrics framework for measuring postponement strategies.

Key Word: Postponement strategies, classification, performance metrics

1. Introduction

Supply chains have to be responsive to rapidly changing markets because of continuously increasing customer satisfaction requirement, product variations, and shortening product life cycle, which increases the complexity of demand forecasting and planning. Postponement is one of the strategies to solve this problem. Postponement is the delay of the point of product differentiation in a production process to the latest possible time (Lee, 1993). The value of postponement is the value of information: as production decision time can be delayed, then more information about the customer demand will be received and analyzed (Lee and Whang, 1999). Hence the quality of decision will be optimized. Consequently, it improves the quality of the demand forecast as the forecasting point moves closer to production period (Bitran et al., 1986; Fisher and Raman, 1996). It also allows flexibility in production scheduling to actual demand resulting in a more responsive supply chain network (SCN) (Lee and Whang, 1999).

Since the concept of postponement in marketing was first defined by Alderson (1950), its application and scope has expanded to areas such as manufacturing and distribution, and recently, to product and process re-design. Past classifications of postponement strategies focus mainly on manufacturing and distribution. With the increased emphasis on supply chain management, we feel the need to re-consider the postponement strategies that also encompass other SCN aspects. We also observed the lack of a comprehensive and exact performance measuring system for postponement. We summarized and classified existing postponement measurements into a framework of performance metrics for postponement strategies.

The rest of this paper is organized as follows: Section 2 discusses the background and motivation for postponement. Section 3 compares and classifies the postponement strategies. We present a

performance measurement framework for postponement strategies in Section 4 and conclude in Section 5.

2. Background

Postponement was first defined as a strategy to postpone changes in form and identity to the latest possible point in marketing (Alderson 1950), and later extended to manufacturing and distribution sites (Zinn and Bowersox,1988). The concept was applied to product design and/or manufacturing process so that the decisions on time and quantity of a specific product being produced can be delayed as late as possible. This idea is also known as *delayed product differentiation* (Zinn and Bowersox,1988; Lee, 1993; Lee and Billington, 1994; Lee and Tang, 1997; Aviv and Federgruen,1998, Lee and Whang, 1999, van Hoek, 1999). Bowersox and Closs (1996), and Lee and Tang (1997) used the *risk pooling* concept on the logistics postponement strategy by stocking differentiated products at the strategically central locations that balance between inventory cost and response time. Other related concepts include the *point of differentiation*, which refers to the stage in the SCN in which takes place, and the *level of postponement*, which refers to the relative location of the differentiation point. For example, in the HP Deskjet printer case, HP decided to perform local customization in European countries for the printer line by postponing the final assembling procedure: storing the semi-finished products in the local warehouse and carrying out the local customization process at the distribution centers in Europe (Lee, 1993). This strategy enabled the company to reduce the inventory level while maintaining or even increasing the customer service level. Other examples, such as Benetton Case (Harvard Business School, 1986), IBM Case (Swaminathan and Tayur, 1996) and so on, show the great success and the extent of postponement implementation.

In summary, the implementation scope of postponement was initially limited to the manufacturing and close-fitting activities, such as distribution. In recent years, the concept spread to other stages, which are once regarded having loose linkage with manufacturing, along the SCN (or may be called as cross-organizational approach (van Hoek, 1999)), such as sourcing. The postponement becomes a strategy-level activity of an enterprise, and requires close cooperation with other attendees in the chain.

2.1. Motivation

Postponement was first implemented in manufacturing stage due to strong incentives to reduce cost and improve service level while product variety increases. Expanding product variety, caused by both producer-based motivation (Lancaster, 1999) and consumer-based motivation (Chong et al, 1998; Kahn, 1999), and high customer service provision are two major challenges for manufacturers to compete both in regional and global markets (Lee and Tang, 1997).

However, proliferation of product variety brings many consequences. First it increases amount of variable patterns in purchasing, manufacturing, inventory, distribution and marketing management, which makes demand forecast more complex and difficult. To increase the accuracy of the forecast, Research shows that moving forecasting point closer to that period may take effect (Bitran et al, 1986; Fisher and Raman, 1996). Secondly, variety of product in manufacturing process means that more operations stages, at which certain features being added,

are needed. As more procedures are required, correlative manufacturing costs increase. Without optimization, costs usually increase at a rate of 25% to 35% per unit each time variety doubles (Stalk, 1988). Thirdly, because demands of each end product vary over time, and the exact number of needs to special products is often unavailable before manufactured, inventory variability and holding cost are increased. As a result, decision time point is indicated as one of the effective determinants of solve these problems, and how to delay the time point becomes an important consideration to a company.

In the meantime, maintaining a given customer level may be costly. First, there is the trade off between economies of scale and mass-customization in production. On one hand, manufacturers desire to implement production plan based on economies of scale in order to optimize total manufacturing and inventory cost, and reduce the lead-time. On the other hand, while build-to-demand may reduce inventory holding cost and risk of overstocking, it increases lead-time, manufacturing cost and the danger of stock-outs. Secondly, conforming to customer requirement both in quantity and quality while maintaining a certain service level affects the efficiency of whole supply chain management. If the supply of a certain product exceeds its demand, there are unwanted inventory costs throughout the SCN; if demand exceeds supply, there are lost sales, possibly market share and inefficiency of SCN. Thus, the design of products and processes such that the high customer service and supply chain efficiency can be simultaneously met becomes important in supply chain management, and postponement strategy can be an effective way to achieve this goal.

3. Types of postponement strategies

Different classifications of postponement strategies reflect respective perspectives on understanding the postponement strategy. Zinn and Bowersox (1988) summarized five types of postponement: labeling, packaging, assembly, and manufacturing, which were based on the type of manufacturing operation postponed; and time postponement occurred during transportation. Lee and Billington (1993) focused on the view of reducing the variability of production volumes so as to reduce the cost at manufacturing and related stages, and their category comprised form and time postponement. Bowersox and Closs (1996) focused on reducing the risk of anticipatory product/market commitment and defined two types of postponement, manufacturing postponement and logistics postponement. Lee and Tang (1997) considered the variety of design changes in the production and distribution processes, then developed a category comprising standardization of components, modular design, postponement of operations, and re-sequencing of operations. Lee (1998) reevaluated the strategy in the way of delaying the timing of the crucial processes where the end products assume their specific functionalities, features or “personalities”, and described three types of postponement: pull, logistics and form. van Hoek’s (1999) focus was drawn on the interrelation of outsourcing and postponement and he defined time, form and place postponement.

Our categorization is based on the activities taken both in the process and product, due to following reasons: Product realization is based on the activities (of the process); even if product status does not change, the alteration of process will affect the cost and efficiency of the whole chain. The scope of postponement consideration includes seven key stages in supply chain:

sourcing, manufacturing, order processing inventory management, warehousing, customer service and distribution.

Since the supply chain process is related to the time in which the differentiating tasks are performed, the postponement strategy is also associated with time factor. In this view, postponement strategy is to redesign the internal property (location, time and the content of the activities) and the external property (relationship with others activities, or so-called sequence) of each stage in a process. We discuss our categorization in greater detail in the remainder of this section.

3.1 Classification of postponement strategy

Although six categories have existed, it is still necessary for us to develop another classification due to several reasons: first, we believe the possibility to implement postponement strategy has extended the scope to the whole SCN while most of the categories before focuses on manufacturing and related activities and the ones that focus on SCN are somewhat incomplete. Second, analyzing and characterizing the essences of postponement thoroughly may help other researchers better understand postponement.

Our classification of form, time and place postponement is based on the characteristics of production/process in the SCN which describe the basic essence of postponement: (a) *product design* — the specific content of delayed operation, (b) *process* — the delayed time point when the activities takes place in the process, and (c) *place* – the location where the delaying takes place.

Form (or Function) postponement: to redesign the function-added process (referred to the procedures before the product finally come into being) to postpone the point of product differentiation. For example, Hewlett-Packard's LaserJet printers had an internal power supply of either 110 or 220 volts due to different requirements in different countries/regions, so that a specific choice had to be made before initiating manufacturing. By switching to a universal power supply, HP was able to reduce the safety stock level in the power supply, and successfully decreased the total cost of delivering the final product to the customer by 5% annually (Feitzinger and Lee, 1997).

There are two main methods to implementing this class of strategies. One is to standardize the upstream product/process so that the point of product differentiation can be delayed to a later stage. Examples including Lee and Billington's (1994) form postponement (to standardize the upstream stages), Bowersox and Closs' (1996) manufacturing postponement (to manufacture the generic product in sufficient quantities while deferring finalization of features), Lee and Tang's (1997) standardization (to standardize the product so that the family products may be replaced by it), and Lee's (1998) form postponement (to standardize the components or process steps to delay the product differentiation). The other is to modularize the components so that the assembly activity can be postponed to a later stage in the process. Lee and Tang's (1997) modularization postponement (to place functionality in modules which can be easily added to a product) and Lee's form postponement fall into this part.

Time (Sequence) postponement: to reconfigure the process sequence (referred to the sequence of procedures in each stage of the whole SCN) so as to postpone the product differentiation. In Benetton case (Harvard Business School, 1986), it reversed the manufacturing process, “dyeing” and “knitting”, to postpone the dyeing of the garment till after the sweater was completely knitted. This strategy, referred to as operations reversal, led to variance reduction (Lee and Tang, 1998) and allows quick response to customer order. The main consideration of implementing this strategy is the sequence of process differentiation and the added cost of implementing this process reconfiguration.

There are two potential ways to implement this strategy. One is to redesign the process sequence so that production decision based on forecasting can be delayed. Examples include Lee and Tang’s (1997) re-sequencing of operations. The other way is to delay implementation time of activities that determine the form and function of products. Examples are Lee and Billington’s (1994) time postponement (to delay the various product differentiation tasks), Lee’s (1998) pull postponement (to make the decoupling point earlier in the process so that the differentiation tasks can be delayed to the point when customer needs become more clear), and van Hoek’s (1999) form postponement (to delay activities that determine the form and function of products).

Place postponement: to redesign the implemented location of process (referred to the geographic location where the procedures in the SCN take place) in order to postpone the product differentiation. In HP Deskjet printer case (Lee, 1993), HP put off the final assembling activities (the localization procedure), and made the final product at their distribution centers point. It reduced the response time to customer order and inventory cost since risk pooling took positive effect in this case.

This strategy can be implemented in several different ways. The first focuses on delaying the differentiation tasks to downstream in final processing and manufacturing. Zinn and Bowserox’ form (1988) (labeling, packaging, assembly, manufacturing) postponement, Lee and Billington’s (1994) time postponement, Lee and Tang’s (1997) postponement of operations, Lee’s (1998) logistics postponement, and van Hoek’s (1999) time postponement all deal with this issue. For example, a European computer manufacturer (van Hoek, 1996) implemented this strategy by the way that he finished the final assembly of personal computers at its local distribution centers (DCs) in response to customer’s specific order instead of completing the computers at factory. The second focus is on delaying downstream movement of goods. Zinn and Bowersox’s (1988) time postponement and van Hoek’s (1999) place postponement discussed this issue. A special topic in goods movement is Bowersox and Closs’ (1996) logistic postponement, which is a delay in the forward deployment of inventory. An example of this approach is Rover (Martin, 1998), a car manufacturer, who centralized the inventory from his dealers (i.e. all stocks were in his DCs) so that he could respond to customers’ order quickly.

Table 1 summarizes the categories of postponement strategies discussed above, the possible stages in the supply chain where the implementation of postponement strategies would take impact on, and the cost factors that may be possibly affected by the implementation.

[Table 1] Three categories of postponement strategy

Category	Definition	Focus	Scope
Form Postponement	To redesign the function-added process to postpone the product differentiation	To standardize the upstream stages (e.g. Lee and Billington's form postponement, Bowersox and Closs' manufacturing postponement, Lee and Tang's standardization postponement, and Lee's form postponement)	Manufacturing, Integration, Customization, Localization, Packaging
		To modularize the functionalities. (Lee and Tang's modularization postponement, and Lee's form postponement)	Manufacturing, Integration.
Time postponement	To reconstruct the process and producing time to postpone the product differentiation	To redesign the process (e.g. Lee and Tang's re-sequencing of operations, and parallel processing)	Manufacturing, Integration, Customization, Localization, Packaging
		To delay implementation time of activities that determine the form and function of products (e.g. Lee and Billington's time postponement, Lee's pull postponement, and van Hoek's form postponement)	Primary Production, Final manufacturing
Place postponement	To redesign the implemented location of process to postpone the product differentiation	To delay the differentiation tasks to downstream in final processing and manufacturing (e.g. Zinn and Bowersox's form (labeling, packaging, assembly, manufacturing) postponement, Lee and Billington's time postponement, Lee and Tang's postponement of operations, Lee's logistics postponement, and van Hoek's time postponement)	Final manufacturing, Packaging, Labeling
		To delay downstream movement of goods (e.g. Zinn and Bowersox's time postponement, and van Hoek's place postponement,)	Packaging, Labeling
		To delay the forward deployment of inventory (e.g. Bowersox and Closs' logistics postponement)	Distribution

4. Performance metrics framework for postponement strategies

Bowersox and Closs (1996) stated three objectives for developing and implementing performance measurement systems: to monitor historical system performance for reporting, to control ongoing performance so that abnormal processes may be prevented, and to direct the personnel's activities. Although their discussion focused on logistics management, these three objectives are suitable to describe the motivation of postponement performance measurement due to several reasons: first, the design and implementation of postponement affects the

manufacturer's production and logistics function, consequently impacts the whole SCN. Second, some postponement strategies, such as place postponement, require the reconfiguration of the SCN. Third, postponement strategy is essentially an information strategy carried throughout the whole SCN and can reduce uncertainty and improve forecast accuracy (Lee and Whang, 1999).

As a result, a framework of performance metrics to evaluate the postponement effect that thoroughly covers the scope of SCN is a must for measuring the effectiveness of the postponement strategies. Since the implementation requires the re-configuration of the product and/or the process in the SCN, historical data becomes a good source to validate the correctness of the implementation.

However, the metrics associated with measuring the total system impact of this strategy should be carefully studied to properly evaluate a strategy. For example, delaying the final assembling activities may reduce the cost of inventory in-transit and inventory holding cost but increase the total manufacturing expense. Trade-offs always exist in the system. A set of indexes on total cost must be introduced into the performance measurement system to identify the changes in costs caused by postponement strategy. Lee and Tang (1997) used the total relevant cost in their model to achieve this goal. Our challenge is to express the value more completely and more explicitly without overlapping costs.

4.1 Literature survey on postponement performance measurements

Postponement strategy has positive and negative drivers. Positive factors include: positive risk pooling effect (aggregate demand information may reduce the demand variability); higher turnover (or velocity) and lower total holding cost; reaching a better trade-off between economies of scale and mass-customization; and lower total transportation cost in the whole chain. Negative effects include longer production time (not lead time), increased inventory holding cost for per unit, additional implementation cost and inventory investment.

Some of the cost-and-benefit associated with these performances can be explicitly measured since the costs are specifically caused by the implementation. For example, the inventory holding cost per unit for special goods can be directly applied to warehouse cost. Other costs are more difficult to isolate because the benefits may be long-term ones that are difficult to quantify at current time, such as the training of workers at DCs to perform assembly activities in place postponement strategy. Some benefits are significant only at the SCN level, for example, postponing an assembly activity to the DC may lower overall SCN cost, although the cost incurred at the DC is actually increased. Some measures such as customer satisfaction cannot be directly quantified.

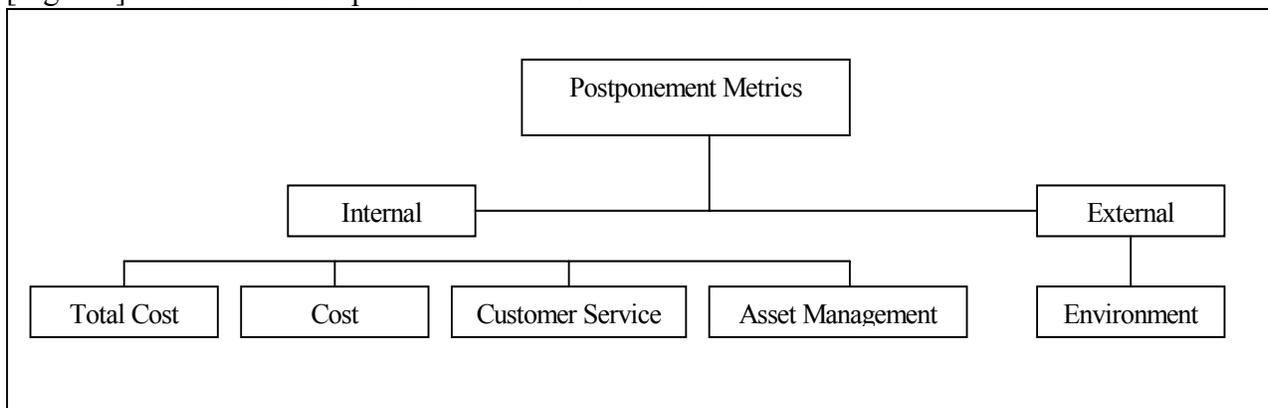
Research on this topic generally focus on one aspect and not on the whole: quantified research focuses on manufacturing cost analysis with a given customer service level (the service level is regarded as a quantitative and constant value in the measurement) (Zinn and Bowersox, 1988; Lee and Billington, 1994; Lee and Tang, 1997; Lee and Tang, 1998; Lee and Whang, 1999); performance indexes have been built to evaluate the cost-and-benefit on functions of a company (often the manufacturer) (van Hoek, 1999), some of which may not be measurable.

Measuring the postponement performance generally focuses on comparing activities and processes to previous operations. Zinn and Bowersox (1988) developed an evaluation system to calculate the direct cost and benefit at a given service level, including inventory carrying cost, process cost like labeling, packing, assembling, and manufacturing activities, transportation cost, and cost of lost sales. Lee and Billington (1994) summarized several cost drivers to be considered in postponement implementation while achieving the same customer service level, which include inventory management, material management, transportation management, re-design planning, reverse management, organizational readiness, and external environment adjustment, and categorized them into measurable and immeasurable types. Lee and Tang (1997) developed a model to calculate the cost-and-benefit of postponement at a given service level, which included one-time design cost, processing cost, inventory holding cost and lead time. van Hoek (1999) developed a measurement system focusing on the production and distribution stages where postponement occurred, of the supply chain in the food industry. The system comprised two main aspects: efficiency and customer service. The survey result showed that physical distribution costs were important in efficiency measurement while the indexes of delivery, product service and innovation were important in customer service measurement.

4.2 Framework for postponement performance measurement

Bowersox’s (1989, 1992) framework measures the internal and external costs within the SCN while Kasilingam’s (1998) framework defines the measurement of individual logistic component. Our performance metrics framework is based on Bowersox but has been modified to fit the postponement issue. We classified the performance measurements identified by various authors in Section 5.1 into internal and external costs. The internal costs are sub-divided four categories: total cost, cost, customer service and asset management, while the external cost comprise environmental cost, as shown in Figure 1.

[Figure1] Classification of performance measurements



The remainder of this section describes the each internal/external cost.

Total cost: it evaluates the system-level costs (see Table 2). It comprises following indexes: total cost; total cost per unit, and total cost as a percentage of sales.

[Table 2] Postponement Total Cost Performance Measures

Performance measure	Definition	Equation
Total cost	To identify the change in systematic costs brought about by decisions	One-time asset investment + Inventory holding costs + Direct labor cost + Material cost+ Warehousing cost + Transportation cost
Total cost per unit	To identify the change in systematic costs per unit brought about by decisions	Total cost/amount of produced goods
Total cost as a percentage of sales	To measure the return of total cost	Total cost/total sales

Cost: the cost incurred by postponement implementation is the most immediate reflection of postponement strategy (see Table 3). It comprises: transportation cost, warehousing cost, process cost on labeling, packing, assembling, and manufacturing, order processing cost, reverse cost, and direct labor cost.

[Table 3] Breakdown Postponement Cost Performance Measures

Performance measure	Definition	Equation
Transportation cost	To measure the cost for goods moving along the supply chain	Cost of goods delivery from supplier to customer + cost of reversal transportation
Warehousing cost	To measure the cost-effectiveness of operating a warehouse.	Fixed cost (building, equipment and fixed payroll) + variable cost (contract manpower, variable utilities)
Labeling process cost	To measure the production cost during labeling stage	Labeling labor cost
Packaging process cost	To measure the production cost during packaging stage	Packaging labor cost
Assembling process cost	To measure the production cost during assembling stage	Assembling labor cost
Manufacturing process cost	To measure the production cost during manufacturing stage	Manufacturing labor cost
Order processing	To measure the cost for order information sharing passing along the supply chain	Cost for order passing from customer to the supplier + cost of shipment information transmitting
Reverse cost	The cost to diagnose, repair and rework returned product	Diagnosing cost + repairing cost
Material cost	The cost of raw materials.	Raw material cost
Direct labor cost	To measure the total production cost	Sum of labor cost in manufacturing, assembling, packaging and labeling + order processing cost + Reverse cost

Customer service: a set of measurements to evaluate customer satisfaction (see Table 4). It comprises fill rate, stockouts, on-time delivery, back-orders cycle time, and total lead time.

[Table 4] Postponement Customer Service Performance Measures

Performance measure	Definition	Equation
Fill rate	To measure the proportion of demands met from the inventory on hand. It is also an important indicator of service level	Order fulfilled/total demand
Stockouts rate	To measure the unavailability of goods	Demand not met in time/ total demand
On-time delivery rate	To measure the rate of deliveries finished in the promised time.	Number of on-time arrivals/total number of arrivals
Back-orders cycle time	The average time from when an back order generated to the time when the shipment received by the customer	Sum of all the back-order time / back-order's amount
Total lead time	The average time from when an back order generated to the time when the shipment received by the customer	(Manufacturing lead time) + transportation time + order processing time

Asset management: it focuses on the utilization of capital investments in facilities and equipment, as well as working capital application to inventory (Bowersox and Closs, 1996) (see Table 5). It comprises inventory turns, inventory holding costs, inventory levels, return on net assets and return on investment, one-time asset investment (redesign, retesting, reconfiguring the equipments and human resource, training, etc.).

[Table 5] Postponement Asset Management Performance Measures

Performance measure	Definition	Equation
Inventory turns	The number of times inventory turned over during the year. It is useful to evaluate the speed of goods moving through a company.	Cost of goods sold/average inventory investment
Inventory holding costs	Cost for holding product in the warehouse	Capital cost + insurance + obsolescence + storage
Inventory level	The order-up-to-level which is the maximum stock the warehouse should held	Safety stock + average inventory during lead time
One-time asset investment	The effect of strategy implementation on cooperation's asset	Redesign cost + retesting cost + cost of reconfiguring the equipments and human resource + training cost and so on
Return on investment	To compare the profit after taxes with total investment	Profit after taxes/total investment
Return on net assets	To compares the profit after taxes with total asset	Profit after taxes/total assets

Environment management: a change in product-component/process could lead to different customs and duties being applied to the items that are shipped from one country to another (Lee and Billington, 1994) (see Table 6) and the value of impact on environment cannot be overlooked. It comprises taxes to local government, localizing degree of the product, and localizing degree of the labor.

[Table 6] Postponement Environment Management Performance Measures

Performance measure	Definition	Equation
Taxes to local government	Average taxes paid to the local government during a fixed period	Taxes per year
Localizing degree of the product	To measure the value created by local material in the final product	Average value of local materials and component per unit/average value of the finished product
Localizing degree of the labor	To measure the value contributed by local human resource in the final product	Average local labor value in the finished product/average value of the finished product

4.3 Discussion

Our metrics framework contains only costs-and-benefits that are directly measurable. There are some hard-to-quantify factors such as organization readiness in implementation, “green” effects (Lee and Billington, 1994), customer perception and so on. Such measures may be developed through wide-scoped surveys and added to the external performance metrics field.

Cost performance in our framework measures in terms of total cost. The average value of specific measures, such as transportation cost per unit, may be more reasonable in some situations and hence be included in the metrics. However several issue to be considered: first, the cost generally contains two components, fixed and variable cost. For example, the distribution cost contains fixed cost of building, equipment and fixed payroll, and variable cost of contract manpower and variable utilities. How to value the fixed cost, like one-time investment, into the average measures need to be carefully considered. One possible solution borrowed from traditional accounting system is to transform the fixed costs into variable ones. Second, the computation method used to count the number of products in a certain period should be carefully picked out. For example, in the computation average cost, how do you define the total number of product? Is it the amount of product being produced, stored, and/or sold? Should the semi-finished products be calculated in since the costs have been generated at the time point, or only the finished products? These are some questions that the metrics users should answer before defining the average cost value.

5. Conclusion

Postponement has been widely accepted to be an effective way to elevate the total benefit from the tradeoff between cost and customer service in the trends of increasing product variety, mass customization and quick response to customer’s need. Over time, the concept of postponement

has expanded from product differentiation in marketing to product/process re-design in the SCN. We surveyed and re-classified existing postponement strategies into three categories, based on differentiation of product, process and place. Literature review showed the lack of a comprehensive and exact performance measuring system. We surveyed various postponement measurements and developed a framework of postponement metrics and discussed the indexes.

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