Postponement Strategies in Dynamic Environment—in terms of Standardization

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Abstract

This study investigates one of the emerging logistics strategies, postponement. A simple model is developed that captures the costs and benefits associated with the postponement strategies for various scenarios. Moreover, this study applies the model to a postponement approach, namely standardization that is motivated by many real examples, and discusses the following three key questions: (1) In each scenario, where is the point of differentiation in the production process (2) How should a firm design its processes to lower the total cost when it is impossible to adjust or it is too costly to alter in a fast-changing environment (3) If an agile firm is able to change its mode of production to respond to a constantly changing environment, how should it adjust the pattern of postponement to lower the total cost

From the decision-making model applying system dynamics, the following conclusions can be drawn. First, in determining the stage at which the point of differentiation should occur, the key variables are the investment cost per operation and the additional cost, including the processing cost and inventory holding cost, that result from postponement. The trade-off between those variables will determine the optimal postponement strategy. We find that when the outside conditions are unfavorable for firms, it may not be advisable to apply the principle of postponement. On the other hand, when the conditions are beneficial, postponement is a better choice.

Keywords: Logistics Strategy, Postponement, System Dynamics, Flexible Decision, Cost Evaluation

Introduction

In the very complex and changing rapidly environment, many enterprises focus on continuously increasing customer satisfaction requirement, shortening product life cycle and raising flexibility, rather than only on quality and cost. In the context, simultaneously lowering costs from mass customization and responding quickly is the main stream of logistics strategy.

Inventory management in traditional logistics strategies used the safe stock of end-product as the way to deal with the demand fluctuation. Usually, the utility rate of resource wasn't efficient enough and had many problem, for example, purchased components inefficiently, designed product unduly, exploited firms unproductive, operated logistics task costly, etc. For recent years, logistics strategy have emphasized on delaying the timing of finishing end-products and combing products in the distribution system so that firms can reduce waste of materiel and supplies derived from demand uncertainty. In this context, redesigning product/process is the popular method to delay product differentiation and that is the idea of postponement (Cheng & Allam, 1992; Xie, 1998).

Postponement is the delay of the point of product differentiation in a production process to the latest possible time. 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. 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. It also allows flexibility in production scheduling to actual demand resulting in a more responsive supply chain networks (Kanet, 1986; Cheng & Woo, 2001).

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 & 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 & Bowersox, 1988; Lee & Billington, 1994; Lee & Tang, 1997; van Hoek, 1999). Bowersox & Closs (1996), and Lee& 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 supply chain networks in which takes place, and the level of postponement, which refers to the relative location of the differentiation point. Generally speaking, postponement enabled firms to reduce the inventory level while maintaining or even increasing the customer service level.

However, to introduce the postponement strategy will lead to additional variable costs and fixed cost from resigning products/progresses and will increase the processing cost and the inventory holding cost per unit. For analysis the change of costs, Lee & Tang (1997) developed a total relevant cost model which incorporates investment cost, processing cost, inventory cost and lead time those would normally be affected by delayed product differentiation and provided a basic measure to evaluate cost change. However, this model only considered the costs from internal activities enterprises and lacked the analysis of environment changes. So we have an idea that through analyzing different scenarios to evaluate the cost changes after introducing postponement strategies, firms could cut down operation cost and raise the flexibility of decisions.

This paper is organized as follows. In second 2, we first review all related papers to know what have been researched. Second 3 illustrate our model to capture the costs and benefits associated with postponement under dynamic environment. In second 4, we consider how our modelcan be applied to some approached motivated by real examples. This is followed by some concluding discussions and suggestions for further research.

Literature Review

Progress in Logistics

In this section, the selection of articles represents the issues and ideas in the decades of the 1970s, 1980s and1990s. Prior to the 1960s, logistics was achieved in a series of fragmented, uncoordinated movements and storage subfunctions. Now, logistics has an expanded role in corporate strategy, which is to create customer value and provide firms with sustainable competitive advantage. So, we bring together some articles (See Table 1), which have made a major impact on the subject of logistics and provide an n overview of the strategic aspects of logistics.

Table 1 Progress in logistics issues

Author	Issues
La Londe, Grabner and Robeson /1970	What are the alternative approaches most commonly used in the corporate development of integrated distribution systems? What were the forces that led to managers' focus on integrated distribution systems during 1960s? What are the forces that will shape the scope and influence of management thinking during the 1970s?
Ballou /1977	The article identified three problems areas that basis for strategic logistical planning: inventory policy, facility location and transport

	selection/routing.
La Londe & Mason /1985	The article showed clearly that a variety of external and internal factors have changed the mix of management required to deal with what were new problems.
Zinn & Bowersox /1988	From the view of logistics cost, authors pointed out five types of postponement: labeling packaging assembly manufacturing time
Manrodt & Davis Jr. /1992	The purpose of the article was to illustrate the historical trend towards responsiveness and pointed out three of the foundational concepts in service response logistics.
Cooper /1993	This paper had assessed the development of global logistics strategy referred to the classification of Zinn & Bowersox (1988) and considered the implication of global logistics strategies for managers.
La Londe & Masters /1994	The purpose in the article was to identify and describe what the authors believed to be the two most important logistics strategies supply chain management and cycle time compression.
McGinnis & Kohn /1997	The authors felt that longitudinal research into logistics strategy would provide insights into practice at different points in time, changes in practice over time, and rates of change over time. The study reported in the article began 1989 and has been replicated in 1990 and 1994.
Claycomb et al. /1999	While prior research has focused on internal and upstream JIT, the research examines the extent to which exchange with downstream customers is JIT oriented.

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Research of postponement strategies

Postponement is one of the logistics strategies burgeoned in the late 1980s. Its core concept is to postpone the task of differentiating a product for a specific customer until the latest possible point in the supply network (Feitzinger & Lee, 1997). That is, all the firms in supply chains must trade off between strategic commitment and operational flexibility (Cvsa & Gilbert, 2002).

Although different classifications reflect respective perspectives on understanding the postponement strategy, the purpose of postponement strategies is identical which is to raise the effects of the whole supply chain. Related papers have arranged and presented in Table 2.

Table 2 Classification of Postponement Strategies

Author	Focus	Category
Zinn & Bowersox /1988	which were based on the type of manufacturing operation postponed and time postponement occurred during transportation	labeling postponement, packaging postponement, assembly postponement, manufacturing postponement, and time postponement
Lee & Billington /1994	focused on reducing the variability of production volumes so as to reduce the cost at manufacturing and related stages	form and time postponement
Bowersox & Closs /1996	focused on reducing the risk of anticipatory product/market commitment	manufacturing postponement and logistics postponement
Feitzinger & Lee /1997	Firms must rethink and integrate the designs of products, the process used to make and deliver products, and the configuration of their entire supply network	Modular design of products, modular design of manufacturing progresses and the design of supply networks
Lee & Tang /1997	considered the variety of design changes in the production and distribution processes	standardization of components, modular design, postponement of operations, and re-sequencing of operations
van Hoek /1999	Which was drawn on the interrelation of outsourcing and postponement	form, time and place postponement
Cheng & Woo /2001	Which were based on the activities taken both in the process and product and based on time factor	form, time and place postponement

Total Relevant Cost Model

To introduce the postponement strategy will lead to additional variable costs and fixed cost from resigning products/progresses and will increase the processing cost and the inventory holding cost per unit .For analysis the change of costs, Lee & Tang (1997) developed a model which incorporates investment cost, processing cost, inventory cost and lead time those would normally be affected by delayed product differentiation.

Supposed that there is a manufacturing system that produces two end-product, where each end-product requires processes performed in N stage. The system has a buffer that stores the work-in-process (WIP) inventory after each operation (Figure 1). To emphasis on the issue of delayed product differentiation, Lee & Tang refer to operation k as the last common operation and vary the products after k.

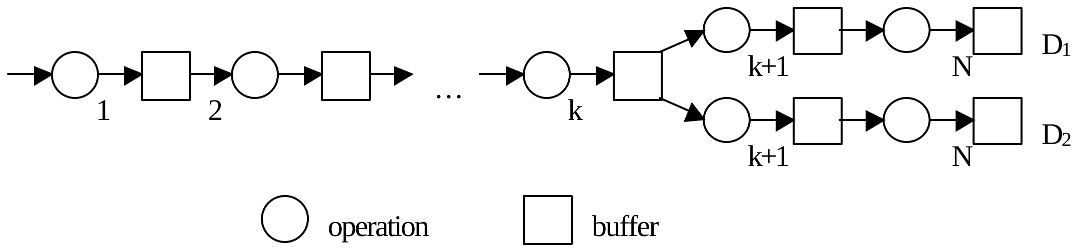


Figure 1 Products 1 and 2 assume their identity after operation k

In Lee & Tang's model, it wants to find the optimal point of differentiation k^* under certain scenario and don't change k^* after the decision has once made. Moreover, average investment cost, the demand of product, the processing cost per unit and the inventory holding cost per unit are all extraneous variables that the relations between these variables and k are considered as given conditions and then to find the minimum of total related cost.

But enterprises usually face a violently changing environment in fact and extraneous variables above will be affected by many factors such as demand, price, exchange rate etc. that may make the postponement unable to implement. In addition, under what scenario should firms postpone the point of differentiation in the production process is another problem. Even if k^* is the optimal decision now, it won't be necessarily so when the environment (or scenario) has changed (See Figure 2).

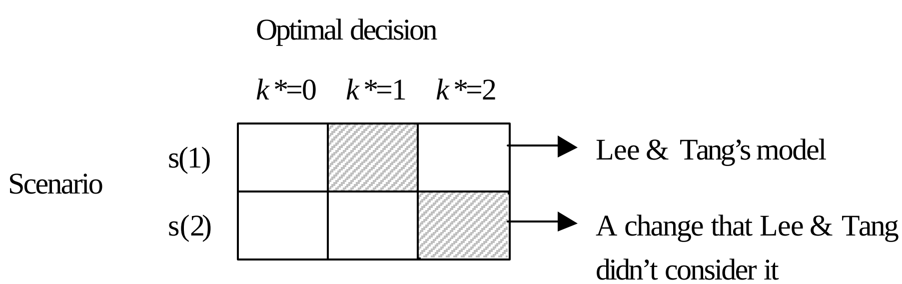


Figure 2 the defect of Lee & Tang's model

Consequently, this study is base on Lee & Tang' s model and enlarges it by bringing into external changes when we design variables. The model in this research is to evaluate when a firm should introduce postponement strategy and when shouldn't as well as should postpone to what stage if the firm need to implement postponement. Therefore, the model not only can make firms to respond to external changes as soon as possible, but also can provide a decision method with operating flexibility when firms want to apply postponement strategies.

Moreover, the study applies the model to two different postponement approaches, namely standardization, which is motivated by many real examples and discusses the following three key questions: (1). In each scenario, where is the point of differentiation in the production process (2). How should a firm design its processes to lower the total cost when it is impossible to adjust or it is too costly to alter in the fast changing environment (3). If an agile firm can change its mode of production to respond to the ever changing environment, how should it adjust the pattern of postponement to lower the total cost

Modeling the Postponement Strategy

To simplify the exposition of our model, we use a simple example to build our model. Supposed there are only two end-products in a supply chain system and the two end-products have no common components if the system doesn't implement postponement. Notice that the two end-products only have one different element. Moreover, the capacity in each firm is infinite that makes a firm can change its producing mode randomly with no additional switching cost. In the context, the supply chain system only faces one extraneous factor - Business Cycle Indicators of Taiwan.

Our model could be expressed as:

- N operating stage
- k last common stage, and $0 \le k \le N-1$
- m_i the demand of product *i* at the end of period *t* $(i=1,2)$ where m_i is normally distributed and $\mathrm{Cov}(m_1, m_2) = r\ s_1 s_2$. Notice that ñ represents the correlation of m_1 and m_2, where $-1 \le r \le 1$. For notational convenience, we let

  $s_{12} = \sqrt{\mathrm{Var}(m_1, m_2)} = \sqrt{s_1^2 + 2r\ s_1 s_2 + s_2^2}$. It is easy to check that $s_{12} \le s_1 + s_2$ for any ñ and that s_{12} decreases as ñ decreases.

- $n_j(k)$ the lead time of operation j when operation k is the last common operation($j = 1 \ldots N$)
- I_j the average investment cost per period with operation j when operation k is the last common operation and $j \le k$.
- $p_j(k)$ the processing cost per unit associated with operation j when operation k is

the last common operation. The total processing cost in operation j was determined by product demand and expressed as $p_j(k)\left[m_1 + m_2\right]$.

- z the "safety factor " associated with the service level for each buffer. Suppose that a buffer faces normal demand with mean m and standard deviation s and that the buffer replenishes its stock by following the order-up-to level inventory (Peterson & Silver, 1979). Then the average WIP inventory is equal to nm and the average buffer inventory is equal to $m/2 + z\,s\sqrt{(n+1)}$ where n is the lead time of this stage. To simplify the model, we assume the WIP inventories are valued as the same as the output of each stage and apply the same safety factor z for each of the buffers in the system.
- $h_j(k)$ the inventory holding cost for holding one unit of inventory at buffer j for one period when operation k is the last common operation. Moreover, the total inventory holding cost includes WIP inventory and the buffer inventory. The total WIP inventory is $h_j(k)\left[n_j(k)(m_1 + m_2)\right]$ because it must concern the lead time $n_j(k)$ in assembling processes. The total buffer inventory is $h_j(k)\left[m/2 + zs\sqrt{n_j(k)+1}\right]$.
- s different business cycle indicators. We base on the monitoring indicators from Council for Economic Planning and Development Executive Yuan, Taiwan, R.O.C. which scores the business cycle indicators as blue, yellow-blue, green, yellow-red and red. Let the demand of products, the investment cost, the processing cost per unit and the inventory holding cost for one unit be variables that changed linearly when the scenario has changed, and can be denoted as $m_i(s)$, $I_j(s)$, $p_j(k,s)$, $h_j(k,s)$. Notice that according to the economics, if the economic circumstance becomes boom, the demand of products will increase that will make $p_j(k,s)$ and $h_j(k,s)$ rise and the availability of money will be loosed which will make $I_j(s)$ drop.

Considering the uncertainty of $m_i(s)$ $I_j(s)$ $p_j(k,s)$ and $h_j(k,s)$, let $Z(k,s)$ be the total relevant cost per period when operation k is the last common operation under scenario s and be expressed as:

$$
\begin{aligned}
&Z(k,s)= \\
&\sum_{j=1}^{k} I_j(s)+\sum_{j=1}^{N} p_j(k,s)\left[m_1(s)+m_2(s)\right]+\sum_{j=1}^{N} h_j(k,s)\left[n_j(k)(m_1(s)+m_2(s))\right] \\
&+\sum_{j=1}^{k} h_j(k,s)\left[\frac{m_1(s)+m_2(s)}{2}+zs_{12}\sqrt{n_j(k)+1}\right] \\
&+\sum_{j=k+1}^{N} h_j(k,s)\left[\frac{m_1(s)+m_2(s)}{2}+z(s_1+s_2)\sqrt{(n_j(k)+1)}\right]
\end{aligned} \tag{3.1}
$$

In equation (1), we could see that demands, investment cost, processing cost per unit and inventory holding cost per unit have changed with the changes of scenario so that produce different total relevant cost $Z(k,s)$. With the optimal solution k^* that makes $Z(k,s)$ minimized, firms could determine postpone to what stage under what scenario.

When external environment changes rapidly or is unable to predict, how a firm with an unchanged production structure should design its product/process to make the total cost minimized? To solve this problem, we suppose that each scenario s is with the probability $\Pr ob(s)$. If a firm determined to let k be the last common operation no matter what the scenario is, the expectation of total relevant cost, $V(k)$, is

$$
V(k)=\sum_{s=\{s_1..s_5\}} \Pr ob(s)\, Z(k,s) \tag{3.2}
$$

From (3.2), we shall find $\min\limits_{k=\{0,1..N-1\}} V(k)$, i.e. when $k=0$, $k=1\ldots$ and $k=N-1$, we should choose a specific stage that will make the expectation of total relevant cost minimized under any scenario as the last common stage and this stage is called as $\bar{k}$ which is the static decision in the dynamic environment. So, $V(\bar{k})=\min\limits_{k} V(k)=V$ and V is the expectation of total cost under the static decision.

If a firm can adjust its production mode without limits, how should it change that will make the total cost least? We have known what is the optimal k^* under each different scenario from (3.1). Now, let W denote the expectation of total cost when each k is the optimal one (k^*) in each scenario and show as:

$$
W=\sum_{s=\{s_1..s_5\}} \Pr ob(s)\, Z(k^*,s) \tag{3.3}
$$

A this time, W is the expectation of total cost under the dynamic decision and means that choosing the k^* corresponding to each scenario to product will make the total relevant cost minimized Further, $W < V$, which will prove if a firm can adjust its production structure followed by the change of environment, it has the cost reduce to least.

Then, this study will use a real case applied the standardization design which is one of the postponement approaches to compare $Z(k+1,s) - Z(k,s)$ and find the optimal postponement strategies under distinct scenarios.

Applications: standardization design

In this section we shall discuss if a firm should introduce postponement strategies under different scenarios and the firm should postpone to what stage. For the purpose, we use equation (3.1) as an original model to analyze a generally used product/process redesign approach, namely component part standardization, which is motivated by real examples in Lee & Tang's research (1997).

The System Dynamics model of standardization

Component part standardization is a widely accepted strategy in improving manufacturing performance while maintaining the required level of product variety to satisfy the customer needs. The term component standardization refers to the situation in which several components are replaced by a single component that can perform the functions of all of them (Perera et al., 1999). Use of the standardized components in several products or in the same product reduces many costs such as inventory costs, R&D costs and material cost.

However, the development cost of a standardized component may be greater than that of each individual unique component since the standardized component needs to be designed to satisfy the requirements of all the unique components. Thus, when making a decision on component part standardization, the firm should consider all the applicable costs throughout the product life cycle.

This example is from a computer manufacturer that produce two type of printers: black ink (mono) and multicolor ink (color) printers. Due to the functionality of these two products, the demands for the two products in each period are negatively correlated. The manufacturing process of the two printers consists of three major steps: printed circuit board assembly (PCA), final assembly and test (FA&T) and final customization (Customization). At each step, different components are used for different end-products. Hence, we can view the manufacturing to printers as two distinct processes and notate as $N = 3$ and $k = 0$ when none of the processes is standardized (See Figure 3).

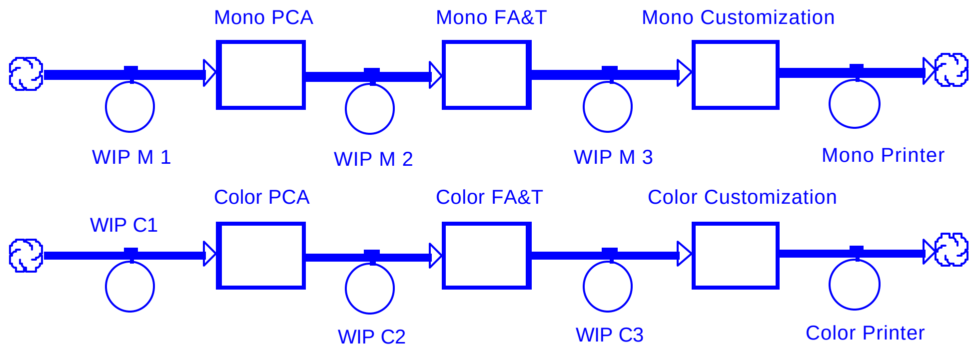
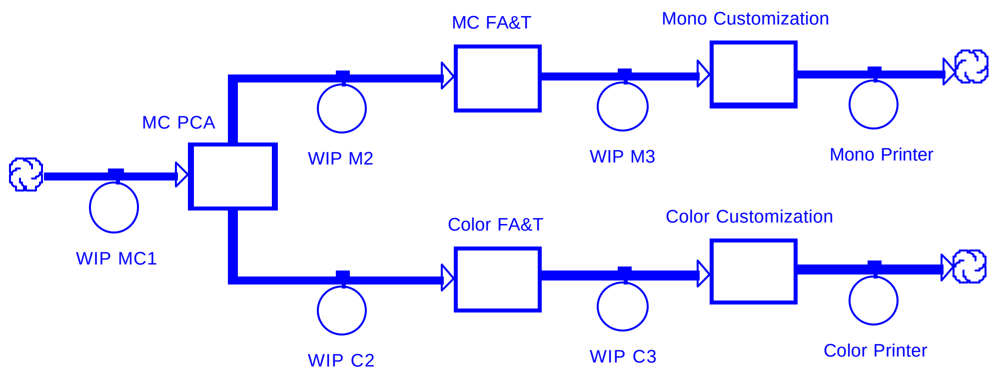
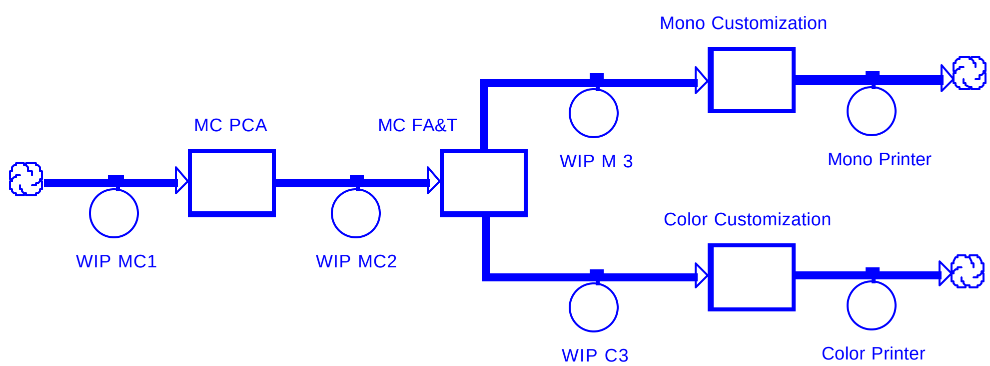


Figure 3 No delayed product differentiation ($k=0$)

In this case, to delay product differentiation could be achieved by either standardizing the PCA stage ($k=1$), or standardizing both the PCA and the FA&T stages ($k=2$) showed as Figure 4.



a: when $k=1$



b: when $k=2$

Figure 4 With delayed product differentiation

Standardizing the PCA stage requires the standardization of a key component, known as the head driver board, for both the mono and the color printer. Due to technical difficulties, the investment cost ($I_1(s)$) for the “common” head driver boards are relatively high. Next, standardizing the FA&T stage requires also the standardization of a key component at the stage, namely, the print mechanism interface. This is a relatively simple task and the investment cost ($I_2(s)$) is relative low. Because the company manufactures the print mechanism interface inhouse, there is actually a strong incentive to standardize the component so as to exploit the benefits of economies of scale. In addition, the lead time isn’t affected neither when the PCA stage is standardized nor when the FA&T stage is.

In this case, $I_1(s) \gg I_2(s) > 0$, $n_j(k) = n_j, \forall j$, and the processing cost can be expressed as:

$$p_j(k,s) = p_j \quad \text{for all j and all s when } k = 0 \tag{4.1}$$

Furthermore,

$$p_j(k,s) = p_j + a_j(s) \quad \text{if} \quad j \le k \quad \text{and} \quad k \ge 1 \tag{4.2}$$

$$p_j(k,s) = p_j \quad \text{if} \quad j > k \quad \text{and} \quad k \ge 1 \tag{4.3}$$

The term $a_j \ge 0$ shows the additional material and processing costs when operation *i* is standardized. Because the common head driver board is much more difficult to develop and process, $a_1(s) > a_2(s) \ge 0$. Then, the unit inventory holding cost can be specified as:

$$h_j(k,s) = h_j \quad \text{for all j and all s when } k = 0 \tag{4.4}$$

Besides,

$$h_j(k,s) = h_j + \left[b_1(s) + ... + b_j(s) \right] \quad \text{for} \quad j \le k \quad \text{and} \quad k \ge 1 \tag{4.5}$$

$$h_j(k,s) = h_j + \left[b_1(s) + ... + b_k(s) \right] \quad \text{for} \quad j > k \quad \text{and} \quad k \ge 1 \tag{4.6}$$

We let $b_j(s) \ge 0$ represent the “additional value added” at stage *i* when it is standardized. In this case, the value of the common head driver board is high so that $b_1(s) \square\ 0$. On the other side, because it doesn't require significant effort to standardize the print mechanism interface, $b_2(s) \approx 0$. Notice that h_j captures the cumulative value added at each operation *i* so it is reasonable to assume that h_j is nondecreasing in *i*.

By substituting (4.1)-(4.6) into (3.1), we can evaluate the total relevant costs $Z(0,s)$, $Z(1,s)$ and $Z(2,s)$:

$$
\begin{aligned}
Z(0,s) &= (p_1 + p_2 + p_3)\left[m_1(s) + m_2(s)\right] \\
&+ \left[h_1 n_1 + h_2 n_2 + h_3 n_3\right]\left[m_1(s) + m_2(s)\right] \\
&+ (h_1 + h_2 + h_3)\frac{m_1(s) + m_2(s)}{2} \\
&+ z(s_1 + s_2)\left[h_1\sqrt{n_1+1} + h_2\sqrt{n_2+1} + h_3\sqrt{n_3+1}\right]
\end{aligned}
\tag{4.7}
$$

$$
\begin{aligned}
Z(1,s) &= I_1(s) + \left[(p_1 + a_1(s)) + p_2 + p_3\right]\left[m_1(s) + m_2(s)\right] \\
&+ \left[(h_1 + b_1(s))n_1 + (h_2 + b_1(s))n_2 + (h_3 + b_1(s))n_3\right]\left[m_1(s) + m_2(s)\right] \\
&+ \left[(h_1 + b_1(s)) + (h_2 + b_1(s)) + (h_3 + b_1(s))\right]\frac{m_1(s) + m_2(s)}{2} \\
&+ z s_{12}\left[(h_1 + b_1(s))\sqrt{n_1+1}\right] \\
&+ z(s_1 + s_2)\left[(h_2 + b_1(s))\sqrt{n_2+1} + (h_3 + b_1(s))\sqrt{n_3+1}\right]
\end{aligned}
\tag{4.8}
$$

$$
\begin{aligned}
Z(2,s) &= I_1(s) + I_2(s) + \left[(p_1 + a_1(s)) + (p_2 + a_2(s)) + p_3\right]\left[m_1(s) + m_2(s)\right] \\
&+ \left[(h_1 + b_1(s))n_1 + (h_2 + b_1(s) + b_2(s))n_2 + (h_3 + b_1(s) + b_2(s))n_3\right]\left[m_1(s) + m_2(s)\right] \\
&+ \left[(h_1 + b_1(s)) + (h_2 + b_1(s) + b_2(s)) + (h_3 + b_1(s) + b_2(s))\right]\frac{m_1(s) + m_2(s)}{2} \\
&+ z s_{12}\left[(h_1 + b_1(s))\sqrt{n_1+1} + (h_2 + b_1(s) + b_2(s))\sqrt{n_2+1}\right] \\
&+ z(s_1 + s_2)\left[(h_3 + b_1(s) + b_2(s))\sqrt{n_3+1}\right]
\end{aligned}
\tag{4.9}
$$

To go on, let us compare (4.7)-(4.8). First, $Z(1,s) - Z(0,s)$ can be shown that:

$$
\begin{aligned}
&Z(1,s)-Z(0,s)= \\
&I_1(s)+a_1(s)\left[m_1(s)+m_2(s)\right]+b_1(s)(n_1+n_2+n_3)\left[m_1(s)+m_2(s)\right] \\
&+3b_1(s)\frac{m_1(s)+m_2(s)}{2} \\
&+z(\sqrt{n_1+1})\left[(h_1+b_1(s))s_{12}-h_1(s_1+s_2)\right] \\
&+zb_1(s)(s_1+s_2)\left[(\sqrt{n_2+1})+(\sqrt{n_3+1})\right]
\end{aligned}
\tag{4.10}
$$

The first five terms on the right-hand side represent the incremental cost incurred when we standardize the PCA stage. The sixth term corresponds to the potential savings due to reduction of inventory at the buffer located immediately after the first stage. However, the fifth term $\left[(h_1+b_1)s_{12}-b_1(s_1+s_2)\right]$ may be positive when b_1 is large enough and makes the incremental costs clearly outweigh the potential savings. Hence, we have $Z(1)>Z(0)$. It means that when the standardization of parts is costly, it may not pay to delay product differentiation. In addition, since $Z(1)>Z(0)$, the optimal $k^*=0$ or 2, i.e. we can eliminate the probability of standardizing the first stage and should either standardize both PCA and FA&T stages or none. However, when $Z(1)>Z(0)$, we need to compare $Z(1)$ and $Z(2)$ to determine the optimal point of differentiation.

$$
\begin{aligned}
&Z(2,s)-Z(1,s)= \\
&I_2(s)+a_2(s)\left[m_1(s)+m_2(s)\right]+b_2(s)\sum_{j=2}^{3}n_j\left[m_1(s)+m_2(s)\right] \\
&+2b_2(s)\frac{m_1(s)+m_2(s)}{2}+z(\sqrt{n_3+1})\left[b_2(s)(s_1+s_2)\right] \\
&+z(\sqrt{n_2+1})\left[(h_2+b_1(s)+b_2(s))s_{12}-(h_2+b_1(s))(s_1+s_2)\right]
\end{aligned}
\tag{4.11}
$$

In (4.11), although the first five terms are positive, the sixth term seems to be negative since I_2 is not large enough, $a_1>a_2\geq 0$ and $b_1>b_2\approx 0$. Therefore, $Z(2)<Z(1)$ that means firms should make PCA and FA&T standardized simultaneously. Then, we shall exam that if it needs to postpone the point of differentiation.

$$
\begin{aligned}
&Z(2,s)-Z(0,s)= \\
&I_1(s)+I_2(s)+\left[a_1(s)+a_2(s)\right]\left[m_1(s)+m_2(s)\right] \\
&+b_1(s)\sum_{j=1}^{3}n_j\left[m_1(s)+m_2(s)\right]+b_2(s)\sum_{j=2}^{3}n_j\left[m_1(s)+m_2(s)\right] \\
&+\left[3b_1(s)+2b_2(s)\right]\frac{m_1(s)+m_2(s)}{2}+z(\sqrt{n_3+1})\left[(b_1(s)+b_2(s))(s_1+s_2)\right] \\
&+z(\sqrt{n_1+1})\left[(h_1+b_1(s))s_{12}-h_1(s_1+s_2)\right] \\
&+z(\sqrt{n_2+1})\left[(h_2+b_1(s)+b_2(s))s_{12}-h_2(s_1+s_2)\right]
\end{aligned}
\tag{4.12}
$$

In (4.12), only the last two terms $\left[(h_1+b_1(s))s_{12}-h_1(s_1+s_2)\right]$ $\left[(h_2+b_1(s)+b_2(s))s_{12}-h_2(s_1+s_2)\right]$ may be negative. So, whether $Z(2,s)-Z(0,s)$ is positive or negative, the key point is the tree variables: I_j, a_j and b_j. But these variables will change depended on the variation of scenarios and the optimal k^* must be determined by different situations.

Through the analysis above, we can know that comparing different $Z(k)$ respectively under different scenarios can acquire k^* that make the total relevant minimized.

4.2. The numerical analysis

For the purpose of defining different scenarios and finding the optimal k^* under different scenarios, we base on the monitoring indicators from Council for Economic Planning and Development Executive Yuan, Taiwan, R.O.C., which scores the business cycle indicators as five scenarios and let $m_i(s)$, $I_j(s)$, $p_j(k,s)$ and $h_j(k,s)$ change linearly as the scenario changed. In addition, the following set of case parameters are employed where (Ernst & Kamrad, 2000)

- $r=-0.99 \Rightarrow s_1=s_2=20 \quad s_{12}=2.8$
- $p_1=p_2=p_3=2$ dollars unit
- $h_1=h_2=h_3=2$ dollars unit
- $n_1=n_2=n_3=3$ minutes unit
- $z=0.9$

By applying (4.7)-(4.9) to the above case parameters the following table of summarized results is obtained:

Table 3 Optimal standardization under different scenarios

s	s1	s2	s3	s4	s5
$m_1 = m_2$	80	90	100	110	120
$p_1 = p_2 = p_3$	2	2	2	2	2
$a_1 = a_2$	0.07	0.06	0.05	0.04	0.03
h_1	3	3	3	3	3
$h_2 = h_3$ b_1	2 0.07	2 0.06	2 0.05	2 0.04	2 0.03
b_2	0.035	0.03	0.025	0.02	0.015
I_1	240	220	200	180	160
I_2	70	60	50	40	30
$s_1 = s_2$	20	20	20	20	20
s_{12}	2.8	2.8	2.8	2.8	2.8
$Z(0,s)$	5384	5994	6604	7241	7824
$Z(1,s)$	5562	6146	6725	7300	7870
$Z(2,s)$	5558	6130	6695	7253	7805
Compare with $Z(k,s)$	$Z(0)<Z(2)<Z(1)$	$Z(0)<Z(2)<Z(1)$	$Z(0)<Z(2)<Z(1)$	$Z(0)<Z(2)<Z(1)$	$Z(2)<Z(0)<Z(1)$
k^*	0	0	0	0	2

Based on the Table 3, we can know how the $Z(k)$ changes when a firm delays the last common stage to different phases under distinct scenarios and can obtain the optimal k^* where the $Z(k)$ is least. Hence, each scenario will generate its own cost structure and has different k^*.

According to the data from Council for Economic Planning and Development Executive Yuan, the total scores of monitoring indicators from Jan 1968 to Feb 2002 in R.O.C. could display as the red is 18%, the yellow-red is 22%, the green is 33%, the yellow-green is 15% and the blue is 12% (refer to appendix A). To get the probability distribution and the results in Table 3 into $V(k) = \sum_{s=\{s_1..s_5\}} \Pr ob(s) Z(k,s)$, then, $V(0) = 6725.84$, $V(1) = 6831.593$ and $V(2) = 6796.633$. Consequently, when the external environment changes rapidly or is unpredictable that a firm can't adjust its production mode immediately, choosing $k = 0$ will let the firm respond to the external change with the lowest expectation of total cost ($V = V(0) = 6725.84$) and $\bar{k} = 0$ is the static decision in the dynamic environment.

On the side, if a firm can arrange its production mode without limit, it should choose $k = 0$ when $s = s_1 . s_4$ and choose $k = 2$ when $s = s_5$. To get the result into (3.3) and tie in the probability of each scenario happens, we can obtain $W = 6722.459$ that is the expectation of total cost under the dynamic decision in the dynamic environment. Due to $W < V$, we can argue that a firm can lower its cost least if it can alter following the external changes. Notice that the difference between W and V isn't quite large in this study. Besides the design problem of our model, the reason may be the additional switching cost from changing production mode. If a manufacturer considers the switching cost, it may be not willing to adjust its mode immediately when the environment changes just now. Because the basic assumption in this research doesn't consider the switching cost, we don't exam the event.

In this section, we have used a simple case exam our model in section 3. For the problem of how to determine k^* in different scenarios, postponing to what stage is decided by the trade-off among I_j, a_j and b_j. If the cost of standardization is quite high and take account of additional processing costs, firms aren't necessarily willing to standardize until the business cycle booms and the demand of products expand that make I_j and a_j lower to certain level.

Besides, if operation j standardizes and the saving of inventory cost is larger that the expanse of investment cost and processing cost, firms will be more willing to standardization design.

5.Conclustion

We have presented a dynamic model to evaluate the costs associated with different scenarios in which the product differentiation is delayed through standardizing component part. Such postponement may incur some investment costs and additional processing costs, but lower inventory costs. Moreover, these cost factors will change following the external environment. In terms of the static decision in the dynamic environment whenever a firm isn't able to alter its production mode, choosing $V(\bar{k}) = \min_k V(k) = \min_k \sum_{s=\{s_1 .. s_5\}} \Pr ob(s) Z(k, s) = V$ can make a firm to respond to various scenarios with the lowest expectation of total costs. In terms of the dynamic decision in the dynamic environment whenever a firm can adjust its mode, choosing the k^* of each scenario and getting them into $W = \sum_{s=\{s_1 .. s_5\}} \Pr ob(s) Z(k^*, s)$ can make the total costs minimized.

Generally speaking, postponement is a kind of strategy or principle. When enterprises introduce it, there are many kinds of variation. Although our model is only applied in standardization design, it could be used in different kinds of postponement strategy to find some common principles.

In our further studies, we shall apply our model to more kinds of postponement strategy to help enterprises determine the problem of designing a product/process. We also shall apply this research to different products or different industries because the focus of cost factors may be different in each industries. Moreover, we plan to add other cost factors to expand our model. In the current model, we don't think about the switching cost which may be a very important factor to influence manufactures' decisions.

Appendix A: Total Scores of Monitoring Indicators in 1968-2002

Year\Month	1	2	3	4	5	6	7	8	9	10	11	12
1968	37	39	41	42	43	44	44	45	42	38	37	32
1969	31	31	31	31	31	33	34	34	35	34	34	35
1970	36	34	34	34	35	35	36	36	37	36	35	35
1971	34	35	34	33	32	34	34	34	36	37	38	40
1972	39	38	38	36	36	36	37	39	40	40	40	43
1973	44	45	44	46	47	50	52	52	52	53	54	54
1974	55	50	45	36	32	28	27	24	21	20	19	19
1975	17	16	15	17	20	23	31	36	38	40	46	44
1976	41	40	40	38	33	35	35	32	34	28	29	24
1977	17	20	20	25	27	27	31	29	37	37	37	35
1978	43	33	45	45	51	49	53	53	53	47	50	44
1979	38	49	43	37	32	36	30	28	32	31	26	26
1980	38	35	28	29	29	26	33	29	28	32	31	30
1981	30	24	29	31	27	25	25	24	19	18	17	21
1982	19	20	20	19	17	17	17	19	18	17	19	17
1983	16	19	18	29	31	38	37	39	38	36	42	35
1984	42	39	37	34	37	30	30	27	25	28	21	21
1985	16	19	14	14	14	12	12	13	14	15	15	22
1986	21	19	33	28	29	37	34	39	36	36	38	37
1987	36	40	32	41	39	38	34	36	37	31	35	32
1988	29	33	28	27	31	30	30	31	28	29	33	32
1989	36	34	40	39	34	30	32	27	24	25	24	25
1990	23	27	21	20	17	14	17	17	18	21	20	15
1991	20	19	19	20	23	24	29	27	27	30	30	28
1992	29	29	28	28	24	25	25	25	22	25	21	24
1993	19	23	24	20	20	17	21	22	23	24	21	27
1994	33	29	25	30	30	32	30	33	34	36	39	31
1995	30	34	30	29	28	25	23	21	22	15	13	16
1996	18	18	13	21	15	17	19	20	24	22	26	28
1997	26	24	31	24	24	28	30	26	31	26	28	29
1998	23	27	25	20	19	20	16	22	18	16	19	14
1999	18	17	16	20	22	25	24	23	19	26	26	28
2000	32	30	29	28	29	27	26	28	28	23	17	16
2001	10	10	10	9	9	9	9	11	9	9	10	15
2002	15	15										

1 There are twelve indexes in 1968-1983 years and nine indexes from 1984 to 2002.

2 Above 38 points is red, 32-37 points is yellow-red, 23-31 points is green, 18-22 points is yellow-blue and bellow 17 points is blue.

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