Simulation-Based Analysis of Postponement Strategy Effect under Various Supply Chain Configurations

by

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Abstract

With the stream of time, business environment is growing complicated and consumers’ wants diversified more and more landing corporations in a difficult situation to consider an assortment of various goods and a high level of service at the same time.

But the production method with which supplies many types of products sustaining a high availability accompanies indispensable cost burden caused by inventory, and in case demand uncertainty is high, such cost increases more. So some corporations started to use "postponement" strategy which postpones the whole or a part of production process until the time when consumers’ purchase are confirmed for a raise of service level and a cutdown of inventory costs, and various ways and views of studies on the postponement are under way centering around Europe and North America.

But a recognition or systematic study on the postponement as a corporate strategy is unsatisfactory level yet, and it’s also true to see any successful postponement case till now. Accordingly, this study aims to make up a framework which bolsters a decision making of postponement strategy enforcement on the basis of its previous quantitative study and in addition
to it, to evaluate its effect in various market environments.

And organizes a decision making model related to feasible or infeasible postponement making the total cost of a scale for evaluation of strategic validity, with a comparison of postponement effect under various alternatives using ‘ARENA’, a simulation program relevant to production and physical distribution system.
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I . Introduction

1. Research Background

Changes in internal and external corporate environments reflect on market directly. As corporate capabilities and managerial environments have been changing due to an advancement of technic and information, market condition also has been changing following it. About such changes, Davis(1987) asserted as the [Figure–1] that the early form of market was regional unit until it was integrated centering around distributions hub, and it again went through subdivision process, until it finally appeared as a developed form of products market for individual costumers.

[Figure–1] The development of markets (Davis, 1987)

Consequently, in consideration that corporations create profit by satisfying their consumers, their tasks in hand to satisfy individual costumers would surely grow heavier, and so most corporations would seek a solution to the matter by producing more various products. But it’s not that easy to reflect needs of countless costumers, and though that’s possible, a cost burden due
to an enlargement of goods assortment would accompanies by all means. Accordingly, corporations should carefully consider a relation between service level for their customers and cost, and this has been one of most difficult task which corporations confront.

Under such situation, corporations have been making efforts to cutdown the cost caused by increase of product sorts for a long time, and it includes information and forecasting system build-up, special transport means development, factory automation etc. But such way requires lots of investment costs and long time, and its burden could be even prolonged, in consideration that the way generated from a long decision making.

Thus, since the mid - 1980s, some corporations started to use the postponement strategy which satisfy their costumers’ demands and reduce inefficiency caused by an extension of product lines simultaneously by redesigning products or a part of production process to change a stream of supply chain accelerating concerns and studies about it.

2. The Purpose of the Research

As previously mentioned, the postponement is not new idea, and yet many sorts of restriction occur in practicing it as corporate strategies, with not so much activation compared with the studies results on the matter. For the corporations, the core issue to be considered in practicing the strategy is an environment at which the corporations are now, and whether or not of the economic validity of the strategy under that environments. Thus, for a decision making of the postponement, the present state, as well as the changed state after the strategy being done, should be clearly defined, and
need to analyze postponement effects by various states without practice of the strategy. Accordingly, this study lays a deduction of strategic environment about postponement trial in the global supply chain as its purpose, and will carry on task in the study as belows.

- Classifying and defining the supply structure in the cases of trial/non-trial of postponement with the compounding of point of differentiation and point of transportation.
- Changing variables of change in demand, weight of production cost, etc by each alternative caused by the classification of points of differentiation and transportation, and then analyzing a postponement effect(cost).
- Deducing variables which have effects on a decision making of postponement strategy.

3. Organization of the Research

For an achievement of the research purpose above, this study will add cost variable to a cost model caused by postponement & the point of transportation by Choi(2007) who extended Lee’s(1997) cost model caused by the point of postponement and with it, will bring out postponement strategy forms with different managerial environments by comparing and analyzing an economical effect in cases of trial/non-trial of postponement by scenarios due to compounding of the points of postponement and transportation. And as the next step, this study will classify postponement in trial/non-trial cases into diverse strategic environments by the point of postponement and transportation, and then will make up a flowchart of the two cases by
scenarios to materialize it with simulation, which will be followed by an analysis on postponement effect on the basis of the deduced comparison results of total cost by scenarios. Besides, this study will bring out a postponement form suitable to external environments corporations confront by comparing and analyzing the postponement effects due to variables of unpredictability in demand and weight of production cost which are uncontrollable by corporations while deducing results.

This study is made up of introduction, theoretical background, make-up of study model, materialization by simulation, analysis on result data, conclusion. The introduction will mention briefly the background, purpose, method, and composition of this study, and theoretical background will discuss a theoretical consideration of postponement and its effect, and techniques for push/pull method inventory management which is related to inventory flow being changed by postponement trial/non-trial.

Besides, this study also will look into the studies on the postponement which has directly influenced this study which is attempting to draw out a suggestion point in decision making of postponement trial. Regarding make-up of study model, it will schematize supply chain environments that change to the points of postponement and transportation for the study purpose, and materialization by simulation will materialize each environment using the ARENA, a simulation program relevant to physical distribution & production. In analysis on data results, it will compare postponement effects by scenarios on the basis of simulation result, and analyze economical effect of postponement that drawn out by a change of variable. lastly, in conclusion, it will summarize the study process and result and draw out a suggestion point, and then will discuss the limitation of the study and the future research directions.
II. Theoretical Background

Yang (2007) asserted that there weren’t enough studies which could explain the relation between the lack of understanding in postponement idea, an managerial environment in which corporations are and postponement strategy through the study on the cause of non-activation of postponement.

In this chapter, postponement and its effect would be considered, and techniques for push-pull method inventory management which related to stock flow in case of postponement trial being done would also be mentioned, and then studies on effect and point of the postponement would be looked into.

1. Postponement Strategy

The postponement is a strategy that postpones a special process until a customer’s order is definitely decided, as seen in [Figure-2], a factory makes products wanted by customers up to the process for common parts instead of finishing them as the end products, and when demand is taken place, the parts, the core of customization, are added to common parts and then let them out, and this is the idea of the postponement.
In that customized products, the final process is postponed to other processes, and as the final process is close to the customers, effects of reduction in inventory and lead time are expectable. In case of postponement trial, a burden of inventory due to an unpredictability in demand is shortened compared with a make-to-stock of end products depending on predictability in demand, and so this method has a good point to satisfy customers, various preferences. But in this case, as the differentiation process is done after a real demand has taken place, a lost sales cost could occur due to an increase of delivery time to customers. Besides, as the process cost at the time of postponement being done is raised due to a loss of economy of scale, a postponement trial generates cancelling effect between costs.

2. Inventory Management System

The evaluation guideline on this study’s postponement effect is total cost, and the largest part among it is the cost relevant to inventory, and so
postponement effect would be changed according to an application way of inventory management techniques by which an inventory flow is decidable. With the recognition, this study will look in a stock supplement system in the postponement effect shown model on the basis of understanding of push/pull strategies, the two largest frames of inventory management techniques.

1) Push-based inventory management

Regarding push method of inventory management, it forecasts demands first and decides quotas to market distribution center and retail stores, and then out the applied quantities. This method is desirable when an output exceeds short-term demand quantity in demand, in which a demand forecast, and quotas to the markets should be considered. The actual trial steps of the push system is as follows:

[Figure-3] The step of push inventory control (Ballou, 1992)
2) Pull-based inventory management – Min-Max system

(optional replenishment system) : (s, S) system

(s, S) system is a combined form of Periodic Review System(P) and fixed order quantity system, which is most widely used among all the pull inventory management methods. Under this system, stocktaking is regularly carried out, and a order of 'target inventory level' (S) is taken place when a stock level reaches at a previously settled 'reorder point'(s). That is, when an inventory level exceeds a reorder point at the time check up is carried out, order is not accomplished, and for a accomplishment of a order, an inventory level should be under a reorder point. And the order quantity at that point is (S-s).

[Figure-4] A Min-Max system of inventory control (Feldman, 1978)
3. Literature Review

The postponement accompanies a great change in a process or supply chain at the time of its trial, and as it’s a strategy that able to change forms and points of products and customer interaction, a quantitative analysis from various views should be backed up. As a matter of fact, the postponement idea was arisen from corporate environment, and it’s a very important strategy, and so with respect to study on postponement, quantitative analysis on its effect were mostly conducted.

1) A study on postponement effect

Zinn and Bowersox(1988) classified postponement as to Form Postponement and Time Postponement. Form postponement is a method with which a factory produces common parts corresponding to demand forecast of end products, and when demand is taken place after having delivered them to each DC, the factory added a differentiation process suitable to customers’ demands. On the other hand, time postponement is a method with which a factory keeps end products which are made by forecast, and when demand is taken place, the factory sends the products corresponding to customers’ demand to the distribution center.

In this study, form postponement was reclassified into 4 forms by differentiation stages as to postponements of labeling, packaging, assembly, manufacturing, and total 5 forms postponements with time postponement were brought up. And then, analyzed factors which have effect on postponement strategy through simulation for the 5 differentiation
postponement models and with it, drew out a strategic environment agreeable to differentiation postponement trial. [Table-1] reveals main factors and environments of each differentiation postponement form.

[Table-1] Postponement factors and strategic environment
(Zinn&Bowersox, 1988)

<table>
<thead>
<tr>
<th>Postponement Form</th>
<th>Input Variable</th>
<th>Weight</th>
<th>Environment suitable to postponement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labeling Postponement</td>
<td>Quantity demanded</td>
<td>Not affected</td>
<td>• In case of numerous brands</td>
</tr>
<tr>
<td></td>
<td>Demand uncertainty</td>
<td>0.78</td>
<td>• In case of high cost</td>
</tr>
<tr>
<td></td>
<td>Product price</td>
<td>0.94</td>
<td>• In case of large demand variation</td>
</tr>
<tr>
<td></td>
<td>Number of label type</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Packaging Postponement</td>
<td>Quantity demanded</td>
<td>0.25</td>
<td>• In case of various package units</td>
</tr>
<tr>
<td></td>
<td>Demand uncertainty</td>
<td>0.62</td>
<td>• In case of high cost</td>
</tr>
<tr>
<td></td>
<td>Product price</td>
<td>0.97</td>
<td>• In case of large demand variation</td>
</tr>
<tr>
<td></td>
<td>Number of package unit</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Assembly Postponement</td>
<td>Quantity demanded</td>
<td>Not affected</td>
<td>• In case of various product types</td>
</tr>
<tr>
<td></td>
<td>Demand uncertainty</td>
<td>0.31</td>
<td>• In case of large-volume reduction due to common parts delivery</td>
</tr>
<tr>
<td></td>
<td>Product price</td>
<td>0.77</td>
<td>• In case of high cost</td>
</tr>
<tr>
<td></td>
<td>Number of product type</td>
<td>0.63</td>
<td>• In case of large demand variation</td>
</tr>
<tr>
<td></td>
<td>Volume reduction</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>Manufacturing Postponement</td>
<td>Quantity demanded</td>
<td>0.46</td>
<td>• In case of high weight of law material procured at DC</td>
</tr>
<tr>
<td></td>
<td>Demand uncertainty</td>
<td>0.55</td>
<td>• In case of high cost</td>
</tr>
<tr>
<td></td>
<td>Product price</td>
<td>0.85</td>
<td>• In case of large demand variation</td>
</tr>
<tr>
<td></td>
<td>Weight of raw material procured at DC</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Time Postponement</td>
<td>Quantity demanded</td>
<td>Not affected</td>
<td>• In case of numerous DC</td>
</tr>
<tr>
<td></td>
<td>Demand uncertainty</td>
<td>1.00</td>
<td>• In case of high cost</td>
</tr>
<tr>
<td></td>
<td>Product price</td>
<td>0.27</td>
<td>• In case of large demand variation</td>
</tr>
</tbody>
</table>

Meanwhile, Johnson and Anderson(2000) analyzed postponement effect caused by diverse manufacturing environments such as product type, stock holding level, forecast error through simulation. In this study, one
distribution center and plural markets were hypothesized, that is, as a speculation case which is delivered following individual demand forecast of end products, and postponement case which are connected to differentiation process after being delivered to markets following the whole demand forecast of common parts, and for that two cases, supply chain and cost caused by previously mentioned variables’ change and order fill rate were measured. Its analysis results are shown in [Table-2].

[Table-2] Postponement effect due to a change of manufacturing environment

(Johnson&Anderson, 2000)

<table>
<thead>
<tr>
<th>Manufacturing environment</th>
<th>Postponement effect due to a change of manufacturing environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of product type (2/4/8 type)</td>
<td>The more product types increased, the more postponement effect increased</td>
</tr>
<tr>
<td>Demand balance between products</td>
<td>The more similar in demand between the products, the more postponement effect increased</td>
</tr>
<tr>
<td>Inventory holding level (4/6 weeks)</td>
<td>Postponement effect was sustained regardless of an increase of inventory holding level</td>
</tr>
<tr>
<td>Forecast error (CV=0.1/0.2/0.3)</td>
<td>The more forecast error increased, the more postponement effect increased</td>
</tr>
<tr>
<td>Additional cost due to differentiation</td>
<td>Additional cost, which foster postponement effect due to a rise of product types &amp; forecast error, was increased</td>
</tr>
</tbody>
</table>

2) A study on postponement point

Lee and Tang(1997) recognized the product differentiation came into being as three forms, like standardization, modular design, process relocation, each of which they modeled for economic quantitative vale of postponement for
analysis on the optimum point of differentiation. 'n' this study, lay the postponement as 'N' number of processes in [Figure-5], and hypothesized a case of differentiation of products after the 'k'th process.

[Figure-5] Postponement point (Lee, 1997)

In this process, a contradictory relation between cost variables, which change to a postponement point, was considered prior to postponement trial which drew out a calculated total cost of investment cost, manufacturing process cost, holding cost of work-in-process, buffer inventory for common process.

\[ Z(k) = \sum_{i=1}^{k_c} S_i \cdot \ldots \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot <\text{Common process investment cost}> \]

\[ + \sum_{i=1}^{N_r} p_i (\ddot{r}_1 + \ddot{r}_2) + \sum_{i=1}^{k_c} z_i (\ddot{r}_1 + \ddot{r}_2) \cdot \ldots \cdot <\text{Manufacturing process cost}> \]

\[ + \sum_{i=1}^{N_r} h_i n_i (\ddot{r}_1 + \ddot{r}_2) \cdot \ldots \cdot \cdot \cdot <\text{Holding cost of work-in-process}> \]

\[ + \sum_{i=1}^{k_c} h_i [(\ddot{r}_1 + \ddot{r}_2)/ 2 + z (\ddot{r}_1 + \ddot{r}_2) \sqrt{n_i} + 1] \]

\[ \cdot \ldots \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot <\text{Buffer inventory holding cost}> \]

\[ + \sum_{i=k+1}^{N_r} h_i [(\ddot{r}_1 + \ddot{r}_2)/ 2 + z (\ddot{r}_1 + \ddot{r}_2) \sqrt{n_i} + 1] \]

With respect to a study model presented by Choi(2007), Lee(1997), it is
extended as a global supply chain idea which make much of international environment to seek a more realistic solution to postponement. In this study, a matter was noticed that a settlement of export timing could be a variable to decision making if global supply chain is hypothesized, and that the points of differentiation and transportation both were considered at the same time in segmenting postponement’s strategic form as [Figure–6].

![Diagram](image)

[Figure–6] Postponement and transportation point (Choi, 2007)

Besides, production cost of each country was added as a variable which could be an important factor in postponement trial under the global supply chain. Accordingly, the total cost model for postponement presented by Lee(1997) was reformed.

\[
Z(k) = \sum_{i=1}^{k} S_i \times i(s) \quad \cdots \cdots \cdots \cdots \cdots \quad <\text{Common process investment cost}>
\]

\[
+ \sum_{i=1}^{N_i} p_i(\dddot{\dddot{1}} + \dddot{\dddot{2}}) \times i(s) + \sum_{i=1}^{k} \dot{z}_i(\dddot{1} + \dddot{2}) \times i(s)
\]

\[
\cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots <\text{Manufacturing process cost}>
\]

\[
+ \sum_{i=1}^{N_i} h_i[\dot{n}_i(s)(\dddot{1} + \dddot{2})] \times i(s) \quad \cdots
\]

\[
\cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots <\text{Holding cost of work-in-process}>
\]
\[ + \sum_{i=1}^{k_i} h_i [\sum_{i=1}^{\infty} \frac{1}{i} (s) + 1] \times i_i(s) \]

\[ \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \·

On the basis of above total cost model, this study analyzed postponement effect under each environment caused by compounding of the point of differentiation and transportation through simulation, and drew out a result seen in [Table–3] that the higher the coefficient of variation is, the lower the production cost rate is, and the closer to the form of a developing country with high tariff rate, the more the postponement effect increased.

[Table–3] Postponement cost structure corresponding to demand uncertainty and national index

<table>
<thead>
<tr>
<th>Coef. of Var.</th>
<th>$S_i$</th>
<th>$k_i$</th>
<th>Coef. of Var.</th>
<th>$S_i$</th>
<th>$k_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>original cost rate=0.1, tax rate=15%</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>original cost rate=1.5, tax rate=12%</td>
<td>1 2 3</td>
<td>1 2 3</td>
</tr>
<tr>
<td>C.V =0.2</td>
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<td>193,298</td>
<td>2</td>
<td>954,776</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>174,450</td>
<td>3</td>
<td>1,244,391</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>362,784</td>
<td>4</td>
<td>442,886</td>
<td></td>
</tr>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,082,790</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,436,457</td>
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</tr>
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<td>2</td>
<td>1,448,339</td>
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<tr>
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<td>3</td>
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<tr>
<td></td>
<td>4</td>
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<td></td>
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<td>797,820</td>
<td></td>
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</tr>
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<td>962,387</td>
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<td>2,080,216</td>
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<td>4</td>
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<td></td>
<td></td>
<td>1,098,297</td>
<td></td>
<td>2,889,667</td>
<td></td>
</tr>
</tbody>
</table>
III. Model Construction

1. Problem Definition

If postponement timing and effect, that is, when would it be good? and how large its effect would be?, should be taken as important matter in decision making of postponement strategy trail, and add the matter that corporate strategy trail is carried out by full decision making, those two questions above should be simultaneously considered. Regarding the study on postponement effect that was seen previously, it drew out a proper environment for postponement standing on the variable out of analysis on postponement effect due to a change in variable, but it recognizes postponement as only one form without bringing out a suggestion point due to postponement point.

With respect to the study on differentiation point brought out by Choi(2007), it compared the cost during the postponement directly to analyze postponement effect due to a change in variable. But the corporations take a postponement strategy in consideration of a relative effect which enlarges compared to the case it wasn’t tried, but not the postponement effect itself.

Besides, it missed the fact that the situations without postponement trial could be differentiated by transport point, revealing a limitation in postponement effect analysis on a diverse situation under the global supply chain. And so a desirable way of evaluation on postponement effect should
be a comparison of cost difference relevant to postponement trial/non-trial corresponding to each situation.

Accordingly, this study will classify postponement into cases of trial and non-trial by scenarios of differentiation point/transport point compounding presented by Choi’s study (2007), and grasp a relative effect of postponement due to transportation cost & demand variation, and then derive a good strategic environment for postponement trial under each situation by analyzing a variable which has influence on postponement effect.

Especially, for a case of global supply chain is hypothesized, this study will classify a situation without postponement trial to transportation point as seen in [Figure-7], in consideration of manufacturing process could be placed on the demand site if production cost such as labor cost, cost of law material procurement is low in the demand site without postponement trial, and then will analyze postponement effect by comparing each of them with a case with postponement trial.

<Transportation after assembly>
2. Flowchart of the Simulation

1) Strategic environment of postponement

On the basis of postponement strategy classification based on the differentiation point and transport point by Choi(2007) which mentioned previously, this study will display a increase effect of investment cost, stock holding cost due to each scenario definition and changes in and differentiation and transport points.

① Scenario 1 : Transport and differentiation after purchases

In case of scenario 1, a differentiation process started form after a purchase stage as seen in [Figure-8], and purchase of two types of products from a factory in a supply site occurs simultaneously, and then common parts are sent to a demand site, and a differentiation process starts from a
processing stage with an occurrence of demand.

[Figure-8] Transport and differentiation after purchases

② Scenario 2: Transport after process, differentiation after purchase

In case of scenario 2, a differentiation process started from after a purchase stage as seen in [Figure-9], and a part of differentiation process goes through to a processing stage with an occurrence of demand, and then delivered to a demand site.

[Figure-9] Transport after process, differentiation after purchase

③ Scenario 3: Transport after fabrication, differentiation after fabrication

In case of scenario 3, differentiation process started from after a process
stage as seen in [Figure-10], and a purchase and fabricating for 2 types of products are being carried on at the same time, and common part are delivered to a demand site, and then differentiation process starts from a assembling stage with an occurrence of demand.

[Figure-10] Transport after fabrication, differentiation after fabrication

④ Scenario 4 : Transport after assembling, differentiation after purchase

In case of scenario 4, a differentiation process stated from after a purchase stage as seen in [Figure-11], and an assembling process, one of differentiation process starts with an occurrence of demand and then delivered to a demand site with the assembling process under way.

[Figure-11] Transport after assembling, differentiation after purchase
5 Scenario 5: Transport after assembling, differentiation after processing

In case of scenario 5, a differentiation process starts from after a processing stage as seen in [Figure-12], and the process goes through until assembling stage in a factory in a supply site with an occurrence of demand and then delivered to a demand site with the assembling process under way.

![Figure-12] Transport after assembling, differentiation after processing

6 Scenario 6: Transport after assembling, differentiation after assembling

In case of scenario 6, differentiation process starts from after a assembling stage as seen in [Figure-13], and a purchase and processing, assembling process for two type of products come into being at the same time, and after this stage, common parts are sent to a demand site, and then differentiation process starts with an occurrence of demand.
[Figure-13] Transport after assembling, differentiation after assembling

In relation to the model explained above, an increased cost by scenarios in a hypothesized case with postponement strategy trial, a modularization cost which derived from the compounding of previous stage of differentiation of A and B increased, but on the contrary, the cost of holding common materials reduced thanks to common management of the material in a factory, and no occurrence of surplus stock of differentiated parts thanks to a demand occurrence after a differentiation process.

Meanwhile, regarding the increased cost due to a change in transport points, if the differentiation points are the same, the closer the transport points move to a demand site direction, in other words, the longer the transport points are postponed, the more the tariff rate of the products increased as the end products’s move is being closer, and on the contrary, the cost on facility investment is reduced at a market distribution center, as the weight of differentiation process trial being increased at a supply site.

2) Replenishment process

① Push-Pull inventory management during the time of postponement
With the start of postponement trial, common parts and differentiated parts are recognized as separated process requiring different stock management techniques. In common parts case, a push-method stock management is good which settles quota for a market through demand forecast and then push them out like a speculative strategy, and in differentiated parts case, a pull strategy, which procures as much quantity as demand need, is good, for in this case, requirement occurs after an actual demand occurrence. [Figure-14] reveals the scope of push and pull system application in the whole postponement process.

[Figure-14] Push-Pull inventory management during the time of postponement

② Replenishment process

With respect to stock management techniques previously explained, a decision making & cost calculating process of a stock supplement at market could be shown as below:

i. In case without postponement trial

In case postponement is not performed, as a stock supplement is attained
by forecast demand instead of actual demand, a push-method stock supplement is applied throughout the process. [Figure-15] is the stock supplement process related to the matter above.

[Figure-15] Replenishment process in case of non-postponement

ii. In case with postponement strategy trial

In case postponement is being carried out, stock supplement process can be changed enabling common parts to have risk pooling effect. In other words, if there exists an unpredictability caused by demand variation of final products, a way to reduce the common products’ demand unpredictability is, to standardize the parts through modularization. If a quantity demanded or demand gap between consumption districts appears to be big, a stock level reduction effect in a factory through risk pooling effect is expectable, and [Figure-16] is showing a process for such effect realization.
<Demand Market 1>

Beginning Inventory

Inventory Update

Real demand

Yes

Inventory level of DC1 > 0

Yes

Calculate backorder cost

Calculate lost sales cost

Calculate inventory holding cost

Calculate ordering cost

Calculate total inventory cost

Update procurement quantity

Backorder

Lost sales

Yes

No

No

<Demand Market 2>

Beginning Inventory

Inventory Update

Real demand

Yes

Inventory level of DC2 > 0

No

Calculate backorder cost

Calculate lost sales cost

Calculate inventory holding cost

Calculate ordering cost

Calculate total inventory cost

Update procurement quantity

Backorder

Lost sales

Yes

No

No

[Figure-16] Replenishment process in case of postponement strategy
IV. Numerical Experiment

As there is limitation in revealing irregularly occurring demand or stock move as numerical model, this chapter modelled the previously defined matters. Besides, for plural alternatives to the points of transport and differentiation, this study made up mathematical/logical models for calculation of total cost under each situation using ARENA, a simulation program for production & physical distribution system materialization.

1. Numerical Design

On the basis of previously mentioned postponement strategy and replenishment process, this clause composed a simulation model for an analysis on economic effect by each alternative relevant to postponement. [Figure-17] and [Figure-18] are for S-3, K-3 (in case of transport after assembling, differentiation after assembling are attained), That is, they are simulation models of postponements with a trial and without a trial. In case of postponements which would not come into being, an individual push method stock management is provided for each product on the basis of each product’s demand forecast data for all the process which are conducted in the factory and distribution centers.
On the contrary, in case of postponements with a trial, a factory applies push method stock management techniques through integrated demand forecast for the two products as the parts are standardized up to assembling stage, and in distribution center, applies a pull method stock management techniques which starts package process only when an actual order is triggered.
2. Simulation on Non-Postponement and Postponement

Regarding six alternatives which were defined in the previous chapter, a total cost relevant to postponement strategy with/without trial are revealed as ARENA simulation shown in [Figure-19] and [Figure-20], and parameter values are as shown in [Table-4]

[Figure-19] Simulation on non-postponement
### Table 4: Simulation parameters (Choi, 2007)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weight</th>
<th>Parameter</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Processing Cost</td>
<td>40($)</td>
<td>Safety Factor</td>
<td>0.95</td>
</tr>
<tr>
<td>Average Demand of Product (A)</td>
<td>3,300 (unit)</td>
<td>Tax Rate</td>
<td>15%</td>
</tr>
<tr>
<td>Average Demand of Product (B)</td>
<td>3,000 (unit)</td>
<td>Holding cost / unit</td>
<td>2($)</td>
</tr>
<tr>
<td>Dev. Demand (A)</td>
<td>150 (unit)</td>
<td>Process cost / unit</td>
<td>385($)</td>
</tr>
<tr>
<td>Dev. Demand (B)</td>
<td>80 (unit)</td>
<td>Transportation cost / unit</td>
<td>50($)</td>
</tr>
</tbody>
</table>

*Figure 20* Simulation on postponement
V. Simulation Result

This study analyzes postponement effect under a plural situation due to a demand uncertainty which corporations can’t control directly and weight of production cost between production-consumption district. And on the basis of simulation model which was composed in the previous chapter, simulation for each scenario was carried out for 360 days, and its result is shown in [Table-5].

[Table-5] Postponement effect correspond to demand uncertainty and manufacturing cost index at the production and consumption site

<table>
<thead>
<tr>
<th>Coeff. of Var. (st.dev./mean)</th>
<th>δ_1</th>
<th>δ_2</th>
<th>δ_3</th>
<th>production cost Factory : DC = 0.5 : 1.5</th>
<th>production cost Factory : DC = 1 : 1</th>
<th>production cost Factory : DC = 1.5 : 0.5</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
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<td>1,294,969</td>
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<td></td>
</tr>
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<td>-1,148,028</td>
<td>2,393,524</td>
<td>-1,630,019</td>
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<td>9,085,711</td>
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<td>36,950,069</td>
<td>43,192,342</td>
<td>42,904,222</td>
</tr>
</tbody>
</table>
1. Postponement Effect Corresponding to Demand Uncertainty

One of biggest reason of postponement trial is Inventory Pooling effect which is gained from a standardization of process parts of different products, and such effect grows bigger when the range of demand variation is large. [Table-5] shows that the higher the demand variation grows, the more the postponement effect increases under every circumstances, and this goes with the previous studies results on postponement effect caused by demand uncertainty.

2. The Postponement Effect by Production/Consumption District Production Cost Due to Uncertainty

Regional price level is productive of demand uncertainty due to products or production properties, which could be seen as an index relevant to a managerial environment which manufacturers can’t control arbitrarily. And so, in case of carrying out postponement strategy under the circumstances of uncertainty and regional price and so on combined, a grasp of cost effect which varies with its transport point might be very important in decision making. Accordingly, this study analyzed postponement strategy effect by transport point corresponding to uncertainty and cost weight in production and consumption district on the basis of [Table-5] result, and [Figure-21], [Figure-22] are its results.
[Figure-21] Postponement effect corresponding to uncertainty and cost weight in production and consumption district

(In case transportation point close to the first process : S=1)
[Figure-22] Postponement effect corresponding to uncertainty and cost weight in production and consumption district

(In case transportation point close to the final process : S=3)

1) A case with a little uncertainty

The comparison between [Figure-21], [Figure-22] reveals a large but narrow range of increase of postponement strategy effect under the situation of low cost in a producing district regardless of transport points. This phenomenon could be taken this way that even a bigger relative cost effect, thanks to an inventory reduction, could be gained under the situation, but so much process and high cost in a producing district, obstruct an inventory reduction effect, could still be profitable after offsetting additional process
cost for postponement.

2) In case with great uncertainty

In case with great uncertainty, under the situation that a transport point is close to the initial process, the cost of producing district should be lower than that of consumption district to be profitable for postponement strategy trial, and under the situation that a transport point is close to the final process, the cost of consumption district should be lower than that of producing district to be profitable for postponement strategy trial. It could be analyzed with the recognition that a postponement strategy trial yields an inventory reduction effect which appears as a production cost and inventory holding cost, an analysis is possible.

An inventory reduction thanks to the postponement strategy, will shorten total cost and inventory holding cost in every process. If a transport point is close to the initial process, that is, the weight of process at a consumption district is greater than that at a factory in a producing district, a cost reduction effect out of inventory reduction in consumption district is bigger, and so if a cost of consumption district is higher, a postponement trial effect would be also higher. On the contrary, in case that a transport point is close to the final process, an inventory reduction effect out of postponement at a producing district is greater, and so a postponement trial effect is higher when a cost of producing district is higher.

Consequently, if an inventory reduction effect through postponement is as high as to exceed additional process cost due to a great demand uncertainty, a whether or not of postponement trial should be decided corresponding to a transport point and producing district/ consumption district cost weight.
3. Decision on a Differentiation Point under the Situation of a Fixed Transport Point

For a postponement trial, a decision not only on a transport point, but also on a differentiation point after the settlement of the transport point should be made. Accordingly, this study compared the postponement trial effect caused by the change in differentiation point under the same transport points standing on the simulation results. Its results are shown in [Figure-23].

[Figure-23] Cost effect correspond to differentiation point at a fixed transport point
[Figure-23] shows that a cost effect could be increased a little if differentiation point is postponed under the situation of a fixed transport point, and the great effect of inventory reduction through postponement trial seems have caused by the fact that the longer a differentiation point is postponed, the heavier the weight of common process becomes.
VI. Conclusion and Managerial Implication

A considerable part of this study on economic effect of postponement is a analysis on differentiation forms & points, which made effort of drawing out a variable that influencing postponement, or differentiation point that could analyzes environment or agreeable to a particular situation.

Regarding the study by Choi(1997), it analyzed a postponement strategy under various environment adding a transport point to a previous differentiation point. But by passing over that could be classified due to transport point even without postponement trial, it couldn’t bring up a significant result of analysis on postponement effect or its point under both manufacturing process in a factory and in distribution center.

About the matter, this study classified the cases without postponement trial by transport point, and then analyzed on how postponement effect appears by a demand unpredictability under each environment of transport point, differentiation point, and to the changes in manufacturing cost weight in producing / consumption districts, making this study significant by drawing out a suggestion point for a decision on transport point under various environment, and factors of postponement strategy trial and differentiation point under the state of fixed transport point.

Through the result data, it was confirmed that this study goes with previous studies which are saying that the bigger the coefficient of variation grows, that is, the bigger the demand variation is, the larger the postponement effect grows. And it also showed that the postponement effect due to a change of manufacturing cost appeared differently depending
on coefficient of variation or differentiation point. Besides, with respect to comparison between differentiation points, it was profitable to postpone the postponement for the same transport point.

But the fact that the cost which reveals lost sales cost that could occur from increase in lead time and differentiation process lead time in a factory or a cost reveals physical distribution service level in measurement index for postponement, and product life cycle, quantity demanded for season in simulation demand data are not considered is the matter to be left as limitation in that study, and if an additional study should be backed up in consideration of the matter above, a more objective decision making on postponement strategy under a various circumstance would be presented.
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