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SIMULATION ANALYSIS FOR ERP CONDUCTED IN JAPANESE SMES USING THE CONCEPT OF MFCA

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ABSTRACT

Small and medium-sized enterprises (SMEs), which have limited resources, spend the majority of their time on routine business and have difficulty pursuing goals beyond economic efficiency, such as environmental preservation. In this study, using the concept of Material Flow Cost Accounting (MFCA), a simulation model for the Enterprise Resource Planning (ERP) business flow of a Japanese electronic related manufacturing SME was constructed, and the hidden problems of stock shortage and dead stock were actualized. By analyzing the causes of these problems and by using a tool called Arena OptQuest, an appropriate materials purchasing plan was determined for the company. This solution will improve production efficiency and reduce the dead stock that causes a negative environmental impact. As a result, an improvement in both economic and environmental performance can be achieved.

1 INTRODUCTION

Company activities such as environmental preservation often lead to increased costs. Enterprises, however, focus on profit and economic efficiency. In particular, small and medium-sized enterprises (SMEs), which have limited resources, are very busy with routine tasks and have difficulty pursuing goals beyond economic efficiency.

Recently, the development of environmental accounting systems has advanced, and these systems have been praised as powerful methods of improving economic efficiency while simultaneously protecting the environment. Material Flow Cost Accounting (MFCA), in particular, has received considerable attention for its effectiveness, and efforts have also been made toward the international standardization, i.e., the International Organization for Standardization (ISO) 14051. In this study, the reduction of dead-stock materials (future waste) of the SMEs in Japan is assumed to be a center issue, and by using MFCA through a simulation analysis, the improvement proposal for business process concerning the Enterprise Resource Planning (ERP) systems is made, which can improve production efficiency, improve customer satisfaction and optimize enterprise management for both economic and environmental performance.

The research related to ERP and the application of ERP mainly advances in large enterprises. The efficiency of the whole supply chain, including small and medium-sized enterprises, is also mainly considered from the perspective of large enterprises, and the so-called coordinated effect of the whole system centers on the management optimization of larger enterprises. Few researchers have analyzed ERP from the perspective of SMEs. A framework for analyzing SME supply chains from the perspective of a vertically integrated raw material supplier was presented by Byrne and Heavy (2004). Mosca et al. (2005) presented a case study related to a project for the optimization of the manufacturing process in a small company produces mechanical components and finished products for awnings. Small and medium-sized manufacturing enterprises in Japan, which are in the lower levels of the keiretsu, take a weak stand on their partners, namely the strong customers and the powerful parts suppliers. They are not considered in the optimization of the entire SCM system, or even for environmental preservation.

The small and medium-sized enterprise that was surveyed in this research is a Japanese electronic related manufacturing enterprise (hereinafter called "T Company"), in which a large-scale ERP system partly connected with that of the customers and the supplies was implemented. Customers' frequent changes of the unofficial notification orders and frequent delivery delays by the powerful parts suppliers caused critical shortages of the necessary materials and an overstock of the unnecessary materials to happen often. Moreover, manufacturing efficiency decreases significantly when there is shortage of materials, causing not only a considerable cost for management but also a considerable amount of dead stock. Thus, a huge stock scrap occurs, which creates a substantial environmental burden.

In this study, a simulation model is constructed by the software ARENA to determine the problems of T Company and to find an improvement solution for the company. As shown in Figure 1, the research is accomplished in four phases. The first phase consists of an investigation of the actual conditions of T Company's ERP system flow, including getting orders, stock control, order confirmation, production, and shipping goods. During the second phase, an AS-IS simulation model (the model represents the current situation) is constructed to determine the problem area from the company. However, the problem cannot be found by using this model. In the third phase, the concept of MFCA is introduced into the model and the stock materials, which have the possibility of being regular waste, are treated as the analyzing targets (in the concept of MFCA, they are called negative products). As a result, the problem was actualized, and the realities, such as an enormous stock and a bad manufacturing efficiency, were shown through the simulation model (AS-IS model using the concept of MFCA). Finally, at the fourth phase, the cause for the above-mentioned problems was analyzed and a tool called Arena OptQuest was used to determine an improvement solution. The effectiveness of the improvement solution was confirmed by running the simulation model with the improvement solution values assigned.

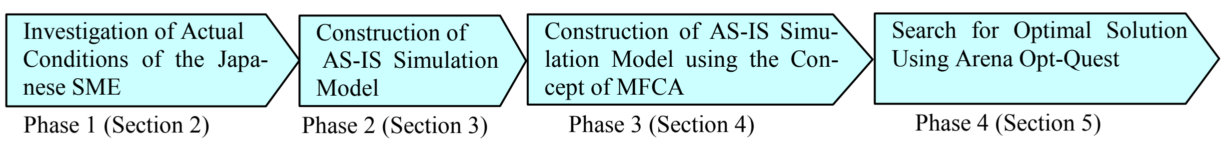

Figure 1: The four research phases

2 INVESTIGATION OF ACTUAL CONDITIONS OF THE JAPANESE SME (PHASE 1)

In this study, the research target T Company is an enterprise that manufactures electronic parts in Shizuoka Prefecture, Japan. The company is also a franchising agency for a famous electronic manufacturer. It produces and supplies parts to several large motor manufacturers in Shizuoka Prefecture. The company's business model proposes to stock electronic parts and to sell these parts as shipping products after production or directly to other companies. As a typical Japanese manufacturing SME, T Company has no negotiating power with its big customers and big suppliers, as illustrated in the smile curve shown in Figure 2.

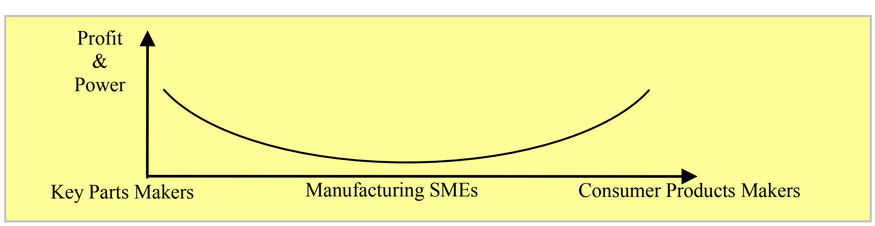

Figure 2: The profit & power of Japanese manufacturing SMEs

During the IT Boom, the selling condition of electronic parts was very good. T Company followed its big suppliers' and customers' booming activities by constructing a cool "IT" system and by introducing a large-scale ERP without understanding either the contents of the system or its purpose.

The mechanism of the production management system for ERP combines the methods of Sequence Number System (SNS) and Material Requirements Planning (MRP). The main business flow is shown in Figure 3 and is as follows.

(1) Getting orders ~ Production schedules (SNS method): The production series number and the schedules are decided according to the unofficial notifications or information from the customers.

(2) Stock Management (Materials Purchasing ~ Warehousing ~ Materials Allocation ~ Materials Delivered to Production Area): The purchasing quantity of materials is decided according to the unofficial notifications of the commodity orders and the production schedules (MRP method). While the same parts may be sold to a different customer, the company will have the stock as its own property. The materials are allocated to a certain production series number or the sales order by the first in first out (FIFO) rule according to the arrival time of the sales order or the unofficial notification.

(3) Order Confirmation ~ Production ~ Shipment: If the necessary materials for production or the sales order that are allocated from the stock and production conditions are ready, the sales staff will confirm with the customers whether the unofficial notification is a real order. If the order is real, production begins. When production is completed, the products are packed and shipped to the customers. When materials are sold directly to the customers, all the processes are the same, except there is no need for production.

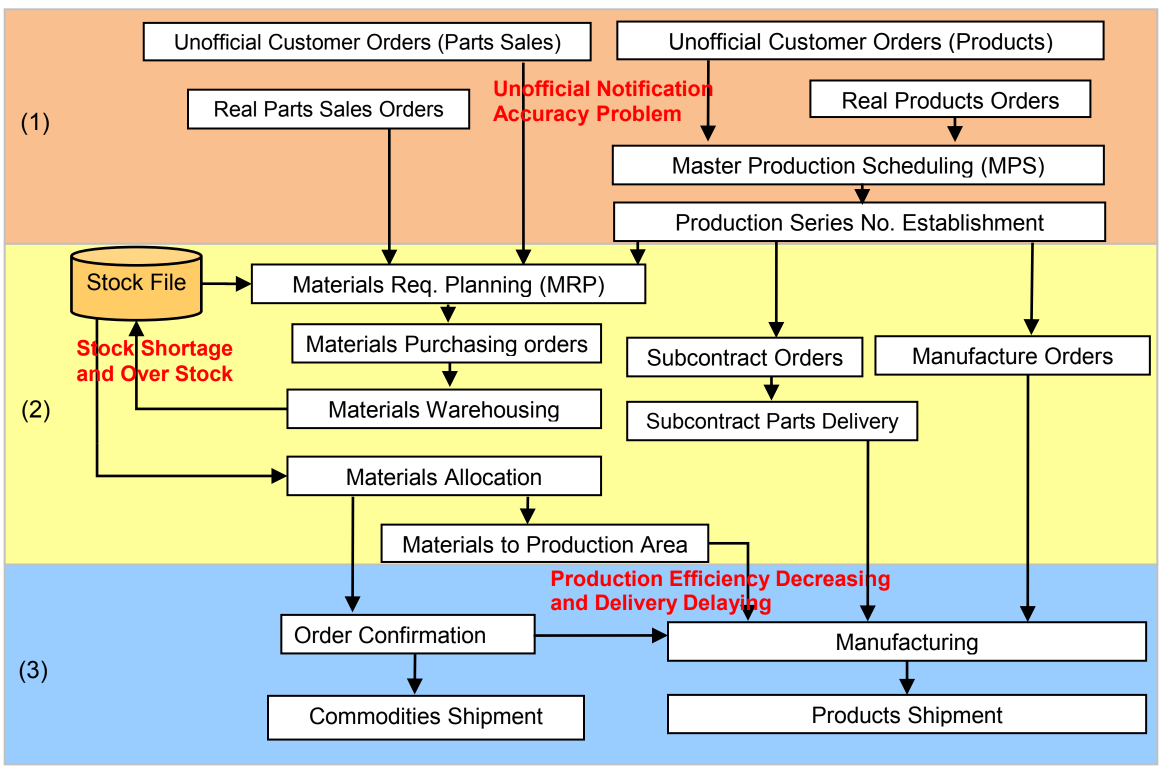

Figure 3: The ERP system flow of T Company

During the IT Boom, production could not meet the market demand, since stocked parts or produced products were sold immediately and since there were not as many problems in stock management. The mechanism of preventing overstock was not included in T Company's ERP system.

Recently, because of the economic depression, unofficial information from the customer has been changed or cancelled frequently, and the lifecycles of the products and parts have been shortened. The following problems have appeared in T Company in recent years.

(1) Critical shortages of the necessary materials and overstock of the unnecessary materials happen frequently.
(2) The manufacturing efficiency decreases remarkably because of stock shortages of necessary parts and increased production costs.
(3) The production lead time becomes longer and customer satisfaction decreases, which has a considerable impact on the company's revenue.
(4) The unnecessary stock increases and causes a huge dead stock. At the end of every year, the dead stock must be scrapped, which causes not only a financing problem but also a substantial environmental burden.

3 CONSTRUCTION OF AS-IS SIMULATION MODEL (PHASE 2)

Given the above-mentioned problems of T Company, an AS-IS simulation model of business flow in T company's ERP system was constructed by using the simulation package, ARENA (Kelton, Sakowski, and Swets 2010).

3.1 Scenario of the Surveyed Products Composition and Production Process of AS-IS Simulation

In T Company, tens of kinds of products and thousands of kinds of the purchased parts to be sold are handled. In the AS-IS simulation model, two types of products ordered by the two main customers of products makers and two types of parts ordered by the two main customers of trading companies are listed, respectively. The composition of the products and the production process are simplified to facilitate the analysis. All the parameters and values are summarized in Table 1.

Table 1: The Parameters and Values Set in the AS-IS Model

			Orders of Customer A	Orders of Customer B	Orders of Customer C	Orders of Customer D
Order Frequency (hours)			every 84	every 120	every 36	every 84
Delivery Time (hours)			TRIA(84, 96, 120) (*1)	TRIA(96, 120, 136)	UNIF(48, 84)	TRIA(36, 96, 120)
Products Quantity (pieces)			UNIF(50, 60)	UNIF(40, 60)	UNIF(120, 200)	UNIF(120, 180)
Product Type			Product A	Product B	Part C	Part D
Materials Including	**a** (pieces)	UNIF(12,36) (*3)	2			
	b (pieces)	UNIF(18,36)	3	1		
	c (pieces)	UNIF(18,36)		2	1	
	d (pieces)	UNIF(24,30)	1	1		1
Production Sequence	**High Speed SMT** (hours)		(1) UNIF(0.25, 0.30) (*2)	(1) UNIF(0.25, 0.30)		
	Manual Mounting (hours)		(2) UNIF(0.15, 0.30)			
	Assembly (hours)		(3) UNIF(0.30, 0.40)	(2) UNIF(0.30, 0.40)		
	Checking (hours)		(3) UNIF(0.15, 0.25)	(3) UNIF(0.15, 0.25)		
	Packing (hours)		(5) TRIA(4, 6, 8)	(4) TRIA(4, 6, 8)	(1) TRIA(4, 6, 8)	(1) TRIA(4, 6, 8)

(*1): TRIA = Triangular, UNIF = Uniform
(*2): (1), (2), … = the production process number
(*3): lead time of procurement (hours)

3.2 The Composition and the Logic of AS-IS Simulation Model

The model is composed of the following five sub-modules, as shown in Figure 4.

(1) Generate Sales Orders: In this sub-module, unofficial notifications for four different customers are generated and addressed with different order numbers, product quantities, structures of materials, delivery times, and so forth.

(2) Stock Management: Purchasing orders are generated, addressed with certain quantities of certain materials according to the present inventory level and the total demand of materials calculated in the first sub-module. The process of warehousing with the logic of increasing inventory level is also built.

(3) Allocate Materials from Stock: The materials are allocated to a certain order by a certain rule (e.g., the first in first out (FIFO) rule, the low attributed value (LAV) rule) that can be adjusted by changing the program. If the necessary materials for the sales orders are allocated from the stock, the allocation signals will be released.

(4) Production & Shipping: The production process of a certain order will be implemented if the order entity receives both an allocation signal sent from the third sub-module and an order confirmation signal sent from the following fifth sub-module.

(5) Order Confirmation: An order confirmation signal will be released if a certain order is confirmed to be a real order. A fake order means that the order was cancelled by the customer and that the relative allocated materials should be returned to the stock.

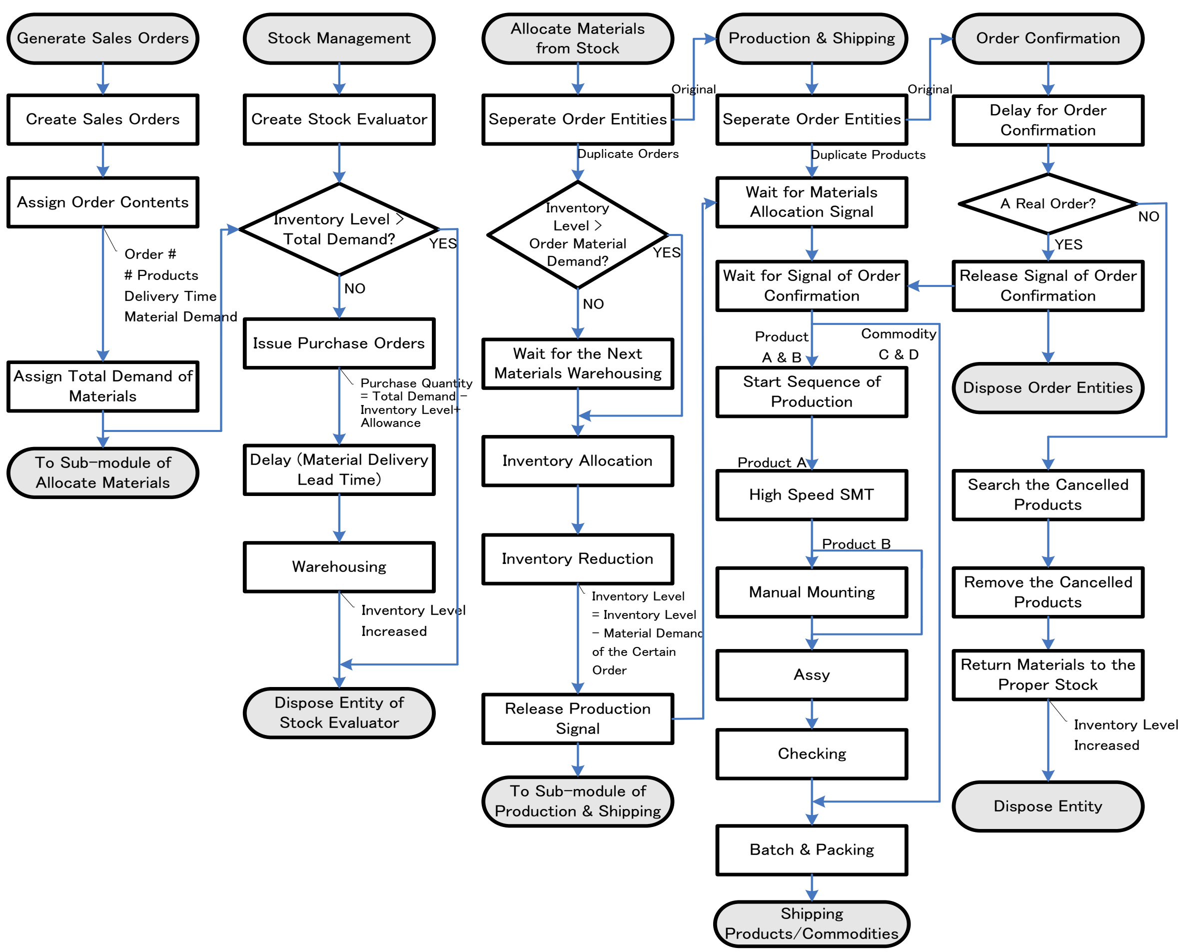

Figure 4: The logic of the AS-IS simulation model

Figure 5 shows the running situation of the AS-IS model by the animation layout. The left part of the illustration labeled "Stock Management" shows the changing inventory level by giving both the plots and the figures. The middle part and the right part show the implementation of the materials allocation, order confirmation, production and shipping process. The lower right figures show the numbers of the orders that shipped and the delayed shipping orders.

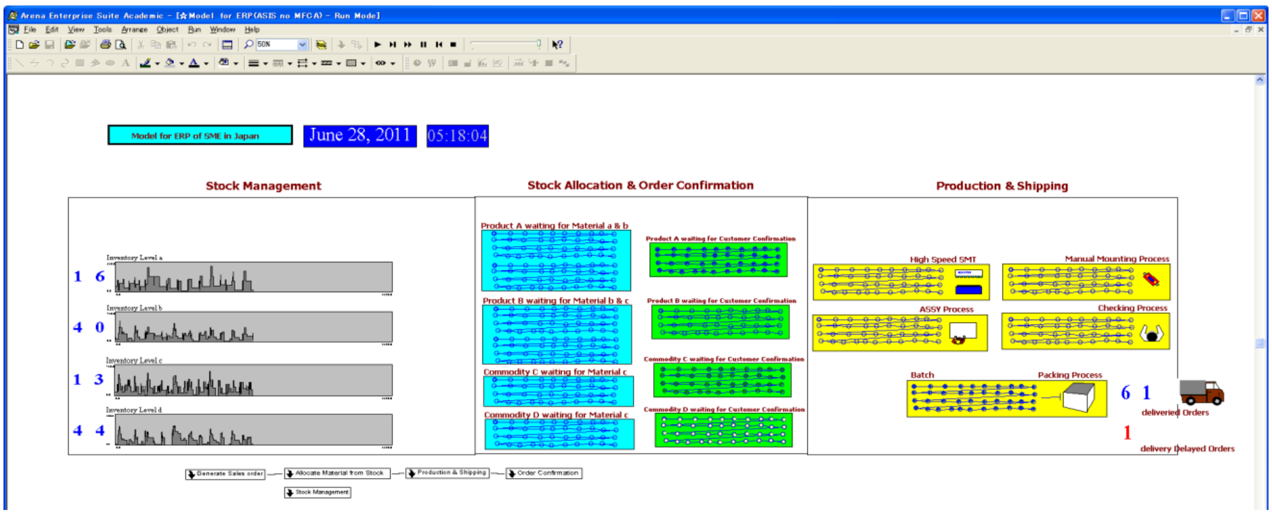

Figure 5: The animation of the AS-IS model

3.3 Execution Results and Cause Analysis of AS-IS Simulation Model

The AS-IS model was executed for 100 replications with the run length assumed to be one year. The average results (at the 95% confidence level) are shown in Table 2. At this point, the problems cannot be identified.

Table 2: The Materials Inventory Condition and Shipping Accomplishment

Materials Inventory at the End of the Year (pieces)	Order Lead Time (hours)	Shipped Orders (orders)	Delayed Orders (orders)
470	312	136	17

As mentioned during phase 1, a mechanism of preventing overstock was not included in T Company's ERP system, so the dead stock was also not reflected in the simulation model. Actually, in T Company, all stock, including the dead stock, are considered assets, and the financial statements do not show the bad situations such as having a huge dead stock during the interim period. At the end of the year, the dead stock showed up and had to be scrapped, and the profits shown in the financial statements worsened; additionally, this wasted stock generates a substantial environmental burden. By the usual accounting method, the dead stock can be called to attention by the concept of cash flow. However, during the routine business activities, the field managers will not consider the materials' abandonment or the dead stock. Therefore, some in-process management techniques should be introduced into the model. In recent years, MFCA has received considerable attention for its effectiveness. The concept of MFCA is attempted to be used to reconstruct the model in order to actualize the problems of T Company.

4 CONSTRUCTION OF THE AS-IS SIMULATION MODEL USING THE CONCEPT OF MFCA (PHASE 3)

4.1 The Concept of MFCA

MFCA is a system to measure the flow and stock of materials in the manufacturing process (raw materials and energy), in terms of physical and monetary units (Kokubu 2008). The prototype of MFCA was developed in Germany as an environmental protection accounting technique. MFCA was introduced to Japan in 2000, and since then, great progress has been made regarding the introduction and application of MFCA to the activities of Japanese enterprises (Environmental Industries Office 2007).

For the international standardization of MFCA, The Ministry of Economy, Trade and Industry proposed the New Work Item Proposal to TC207 (environmental management) of the international organization for standardization (ISO) in November 2007. It was adopted in March 2008. As a result, the working group that did the standardization was set up. It began work for the international standard issue, and ISO 14051 was given from the ISO secretariat to the MFCA standard in the spring of 2011. MFCA is attracting not only Japanese but also worldwide attention (Environmental Industries Office 2010).

The concept of MFCA is as shown in Figure 6. The manufacturing enterprise stocks the raw materials, produces the products through the production activities, and supplies them to the market. These products are considered to be positive products in MFCA. On the other hand, waste is also generated during the process of stocking and production. When the materials are stocked as inventory, because of the quality deterioration or renewal of parts, the materials or the parts cannot be useable for production any longer. When the materials are processed, residues or shavings may be generated. Under the circumstances mentioned above, these materials are all considered waste. Because they may lead to environmental problems, in the concept of MFCA, these materials are all treated as negative products and are considered a loss.

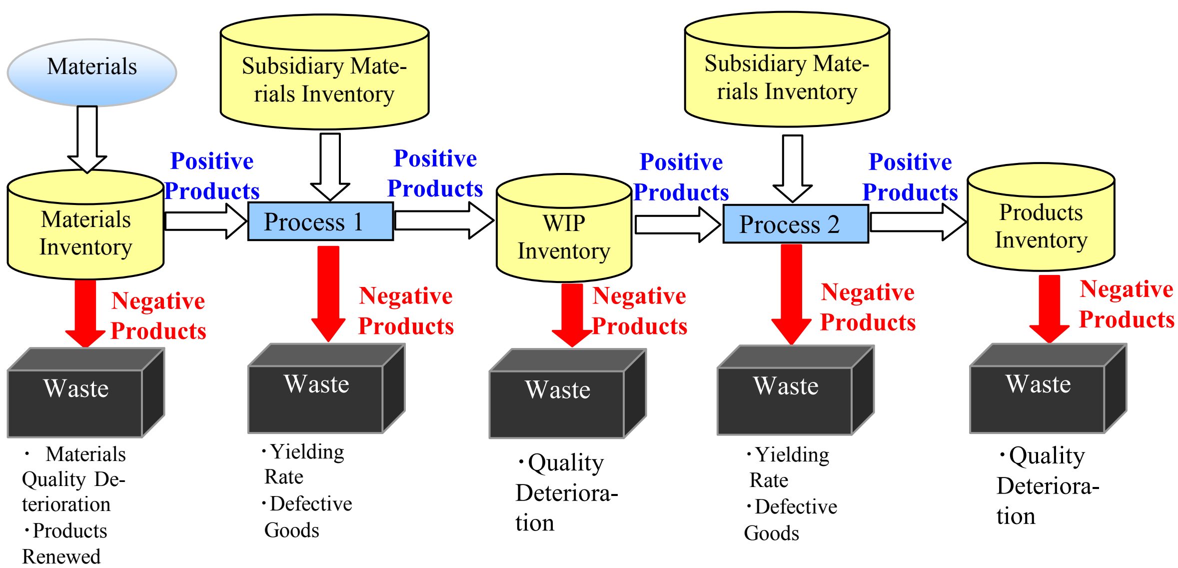

Figure 6: The concept of MFCA (Environmental Industries Office 2007)

Because the main business of T Company is electronic components assembly, the amount of waste generated is minimal during the production process. However, a large amount of immovable stocks are generated every year, and when the end of the term comes, because the parts are not useable any longer, they all become waste. Therefore, in this study, waste from the materials inventory was focused on in T Company and the model was reconstructed by introducing the concept of MFCA.

4.2 The AS-IS Simulation Model Using the Concept of MFCA

To use the concept of MFCA, there is a need to grasp the actual situation of waste generated from the raw materials inventory in T Company. The renewal pattern of the raw material a is assumed to be an example, as shown in Figure 7. According to the product composition list from the customer, material a is renewed every 90 days. When parts a1 are renewed to a2, the parts a1 stocked before cannot be used for production any longer, and they become a kind of immovable stock. Because T Company does not treat the immovable stock as waste during the interim period, huge amounts dead stock are not recognized. When the end of the term comes, the volume of the dead stock becomes large, causing a considerable amount of waste that will influence the profit of the company and that will produce a substantial environmental burden.

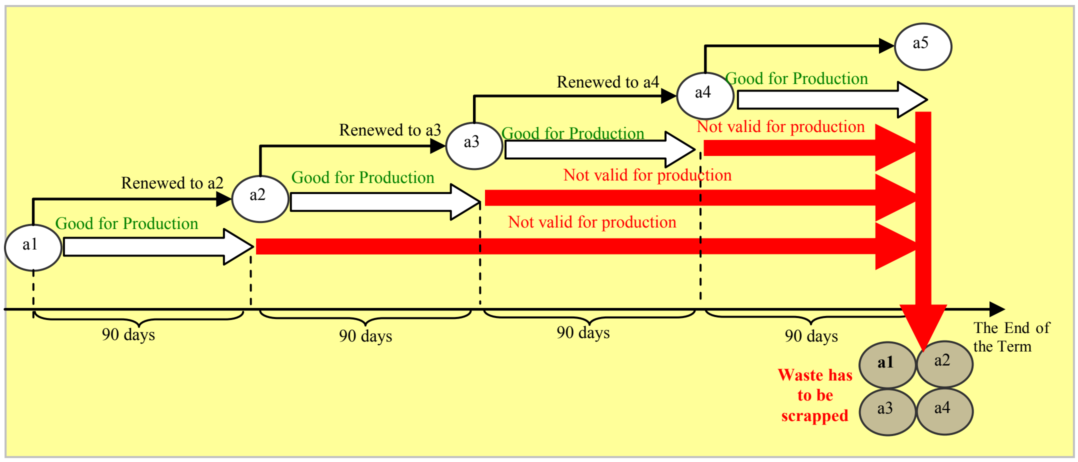

Figure 7: The actual condition of materials renewal in T Company

Considering the reality mentioned above that the immovable stock is caused by a regular renewal of the raw materials, the approach of using the concept of MFCA is attempted in our research. In the routine production activities, the immovable stocks are treated and counted as waste or negative products to actualize the stock problems during the interim period. This concept is shown in Figure 8.

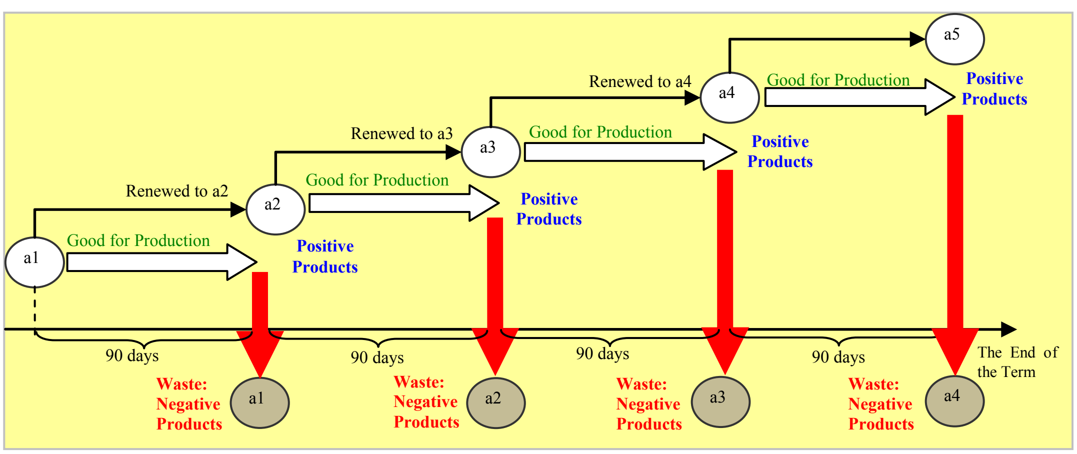

Figure 8: The method of the stock management using the concept of MFCA

The above concept was reflected in the AS-IS simulation model with the addition of the sub-module of Scrap Dead Stock. The logic of model is shown in Figure 9 (the additional parts are enclosed with a red dotted line circle).

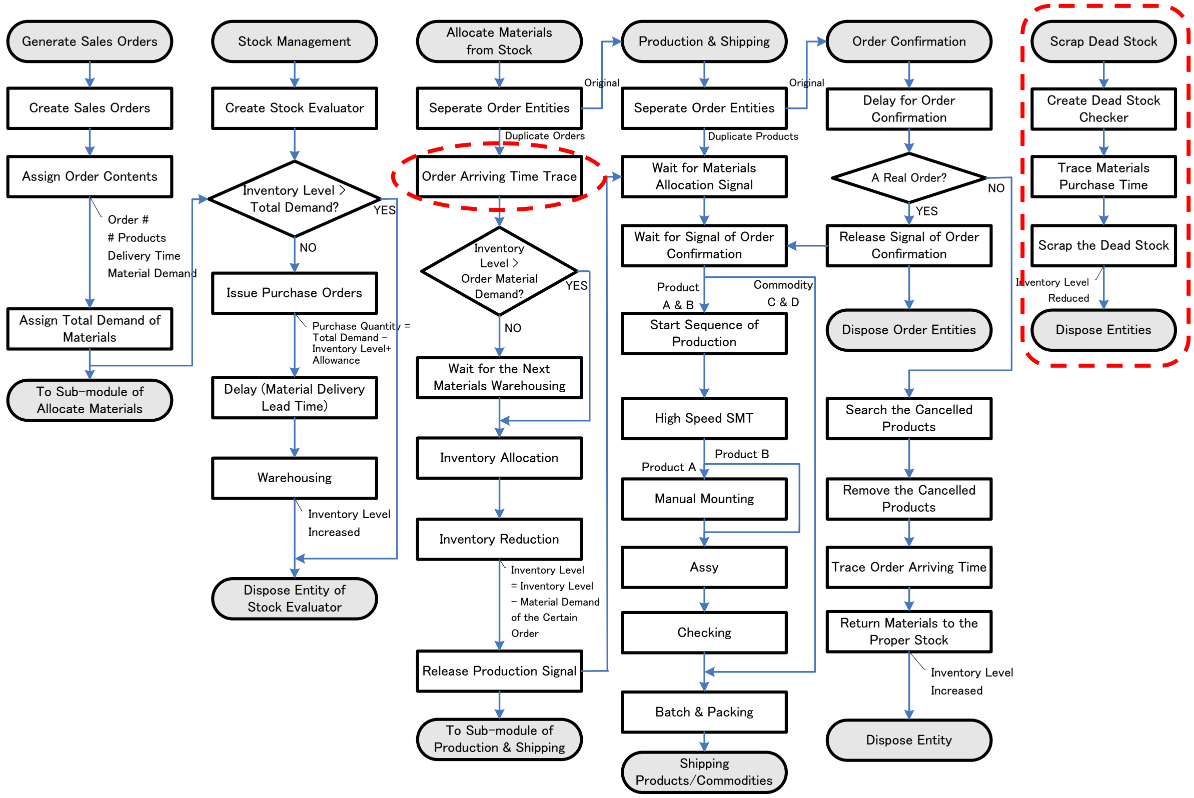

Figure 9: The logic of the AS-IS simulation model using the concept of MFCA

4.3 The Execution Results and the Analysis of the AS-IS Model Using the Concept of MFCA

The model was executed for 100 replications with the run length assumed to be one year. Compared with the results shown from the AS-IS model in 3.3, the average results (at the 95% confidence level) of this model worsened, as shown in Table 3. Through the construction of the simulation model using the concept of MFCA, the useless materials in the stock are reflected as negative products, which are excluded from the orders' allocation objectives. The reality of the decrease in the manufacturing efficiency due to stock shortage and the increase of the dead stock are reflected in real time during the interim period. The problem is actualized, and the necessity for an improvement solution is apparent.

Table 3: Materials Inventory Conditions and Shipping Accomplishment

Materials Inventory at the End of the Year (pieces)	Number of Abandoned Materials (pieces)	Order Lead Time (hours)	Shipped Orders (orders)	Delayed Orders (orders)
452	2584	330	135	26

5 SEARCH FOR OPTIMAL SOLUTION (PHASE 4)

In this section, to determine an improvement solution for the problems ascertained from the analysis of the AS-IS model using the concept of MFCA, an optimization program in Arena called OptQuest was used. To use this tool, the optimal objectives and the control conditions through the path analysis should be determined first.

Figure 10 shows an analytical situation in which the execution process of the ERP system in T Company influences both the economic and the environmental performance. Demand forecast influences all the business activities that have consequence for the management results. There is no doubt that positive activities such as negotiations with customers and collections of accurate unofficial notifications by the sales staff are very important. To accomplish the above-mentioned improvements, incentive and evaluation systems to improve the performance of the sales staff are necessary in addition to the improvement solution for the ERP system. During the implementation of the ERP system, materials purchasing planning is very significant and it influences the other activities considerably, as shown in Figure 10. Inaccurate materials purchasing planning causes stock surplus and stock shortage simultaneously, which not only decreases manufacturing efficiency, which causes delivery delays and customers dissatisfaction (a business economic problem), but also generates dead stock, which increase waste (economic funding issues and environmental problems).

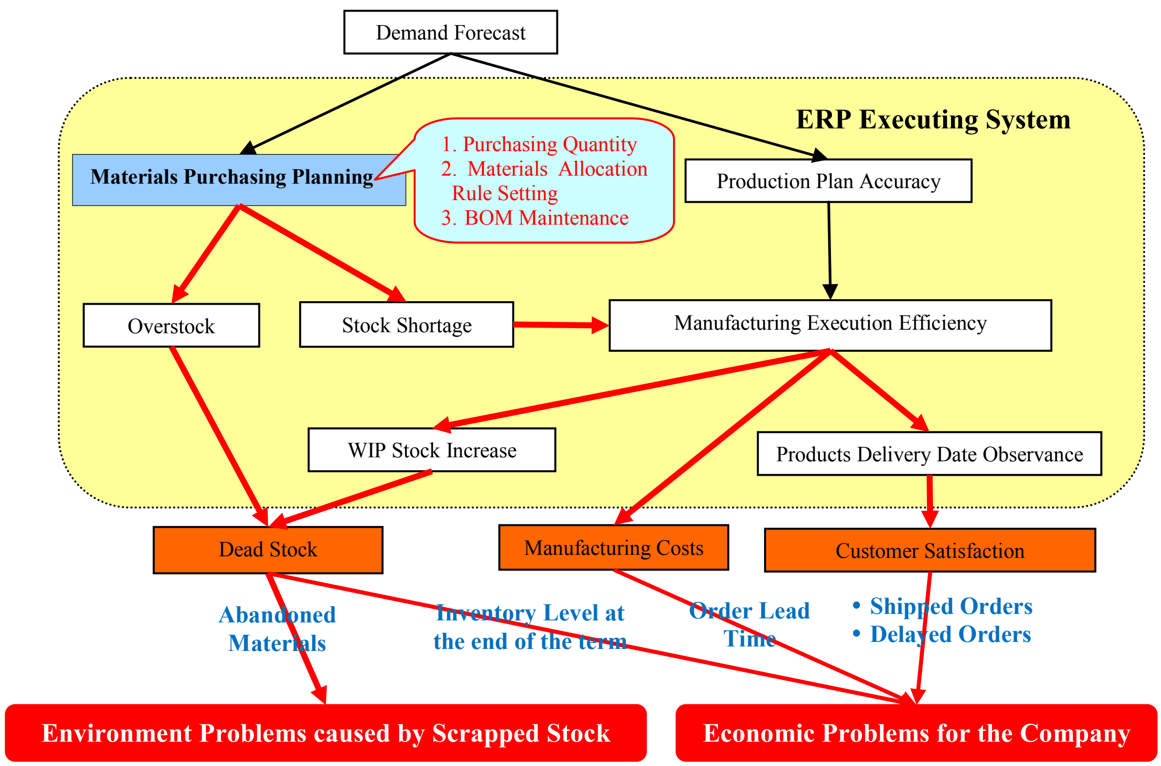

Figure 10: The analytic situation of the ERP system in T Company

Through the interview with the staff members of T Company, for materials purchasing planning in the ERP system, the following two control conditions are very important.

(1) Purchasing Quantity
Purchasing Quantity = Total Order Demand - Inventory Level + Allowance. Here, the lower bound for the allowance was set as the value calculated based on the possible cancelled orders and the upper bound was set as the value based on the biggest order demand quantity in the model.

(2) Materials Allocation Rule Setting
In the improved model, the allocation rule was changed to a combination of the two factors, (a) delivery time and (b) order priority (according to the percentage of certainty of the unofficial notifications of different customers), of which the expression is "Delivery Time + Priority * Priori-

ty Importance", in which the lower bound and the upper bound for the Priority Importance were as 12 (one day) and 136 (the longest order delivery time) respectively.

In addition, the procedure of system maintenance such as updating the bill of materials (BOM) should also be considered when the renewal of a certain kind of materials happening. In T Company, it usually takes one week. However, it can be reduced at most to 24 hours. Hence, the program considering of system maintenance was also conducted.

Since the improvement of the environmental performance is the main issue in this study, the minimization of the amount of Abandoned Materials which are also called negative products in MFCA is set as the objective.

At the same time, the economic improvement should also be considered. Thus, the other indices are set as the constraints detailed as follows (the values are based on the executed results of the AS-IS model).

(1) Inventory at the end of the year<= 470;
(2) Order Lead Time <= 312;
(3) Orders that has been shipped delayed <= 17;
(4) Orders shipped > = 136.

The optimization program Arena OptQuest was executed 1000 times. The average results (at the 95% confidence level) of the best solution are shown in Table 4. Comparing the results of the AS-IS model and the AS-IS model using the concept of MFCA, the values of Environmental Performance and Economic Performance showed balanced results in the improved model using OptQuest.

Table 4: The Simulation Executing Results

Simulation Models	Environmental Performance		Economic Performance		
	Materials Inventory at the End of the Year (pieces)	Number of Abandoned Materials (pieces)	Order Lead Time (hours)	Shipped Orders (orders)	Delayed Orders (orders)
AS-IS	470	N/A	312	136	17
AS-IS (MFCA)	452	2584	330	135	26
OptQuest	**426**	**1655**	**311**	**141**	**15**

By constructing the simulation model for the T Company's ERP System, using the concept of MFCA and searching the optimal solution with Arena OptQuest, an improvement solution was determined. The proper controlled conditions for setting materials purchasing quantities and for allocating rules will lead to a significant reduction of waste and will surely increase order execution efficiency. Moreover, these improvements facilitate to a better environmental and economic performance.

6 CONCLUSIONS

In this study, the effectiveness of the in-process type of management technique of MFCA is confirmed through the construction of the simulation model using the MFCA concept. The abandonment of the dead stock is reflected as the generation of negative products, and the stock problem is actualized during the routine business activities, and thus, measurements can be taken to reduce waste that produces a negative environmental impact. Additionally, by determining an appropriate materials purchasing plan, executable production schedules can be made, which will improve order execution efficiency. As a result, an improvement in both economic and environmental performance can be achieved.

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REFERENCES

Byrne, P. and C. Heavy. 2004. Simulation, A Framework for Analysing Supply Chains. In *Proceedings of the 2004 Winter Simulation Conference*, ed. R.G. Ingalls, M.D. Rossetti, J. S. Smith, and B. A. Peters, 1167-1175. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Environmental Industries Office, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry. 2007. "Guide for Material Flow Cost Accounting (Ver.1)." http://www.meti.go.jp/policy/eco_business/pdf/mfca%20guide20070822.pdf.

Environmental Industries Office, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry, Japan. 2010. "Material Flow Cost Accounting MFCA Case Examples." http://www.jmac.co.jp/mfca/thinking/data/MFCA_Case_example_e.pdf.

Kelton, W. D., R. P. Sadowski, and N. B. Swets. 2010. *Simulation with ARENA.* 5th ed. New York, NY: Mc Graw-Hill Co., Inc.

Kokubu, K. 2008. Material Flow Cost Accounting. Tokyo: Japan Environmental Management Association for Industry. (in Japanese)

Mosca, R., R. Revetria, L. Cassettari and G. Margro. 2005. Simulation as Support for Production Planning in Small and Medium Enterprise: A Case Study. In *Proceedings of the 2005 Winter Simulation Conference*, ed. M.E. Kuhl, N.M. Steiger, F.B. Armstrong, and J.A. Joines, 2443-2448. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

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