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# An Integrated Production Management Model for a Manufacturing System

JaeKyoung AHN†

Department of Industrial and Information Systems Engineering,
Seoul National University of Technology, Seoul, 139-743

# 제조시스템을 위한 통합형 생산관리모형 구축

안 재 경

서울산업대학교 산업정보시스템공학과

Business integration has been considered as one of the most critical success factors that enable the firms to gain competitive edges. Despite this trend, it has also been found among not a few companies that the activities that should be functionally tied with are performed even independently. In this study, an integrated model of production planning and inventory has been developed. Computerization of the production planning activities is proposed and implemented. We also proposed the reasonable inventory levels of each item using historic data of the items, which are composed of safety stock from the given fill-rate, operating stock from the production patterns, and reserved stock from the production planning. This study has helped the firm to have clearer job definition of the related processes, to tightly control the inventory by setting and tracing the reasonable fill rates for every product, and to quickly respond to the market changes through the computerized production planning process.

*Keywords*: production planning, inventory control, integrated production management, business process reengineering

## 1. Introduction

Severe global competition has forced manufacturing companies to adopt "Continuous new product introduction", "Beyond customer expectation", and/or "Lowest price & Best quality" policies. To fulfill these policies, however, is accompanied with the difficulties that one should have major successes in quality and productivity improvement at the same time(Browne, 1988). In most companies with the successful improvement, effective and agile manufacturing systems have been established through focusing attention on their business as a process rather than a series of individual activities, reengineering/ integrating the processes with the team-based implementations, and finally activating continual change mechanisms(Grover and Malhotara, 1997).

This business integration has been considered as one of the most critical success factors that enable the firms to gain competitive edges. Despite this

This study was supported by the research fund of Seoul National University of Technology
† Corresponding author : Professor JaeKyoung AHN, Department of Industrial and Information Systems Engineering, Seoul National University of Technology, Seoul, 139-743, Korea; Fax +82+02+974+2849; e-mail jkahn@snut.ac.kr
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trend, it has also been found among not a few companies, specially mid-small size companies, that entire business integration apart, the activities that should be functionally tied with are performed independently(Byrne and Markham, 1991). In particular, sales/ production/inventory management activities are often the cases. Even in New Economy systems, mutually reinforcing resources that are consistently tied with each other are a major component to construct a strong value proposition (Rayport and Jaworski, 2001).

In this study, an integrated model of production planning and inventory has been developed.

## 2. BPR for the sales/production/inventory groups

The targeted company has seen a rapid revenue growth (about 33% per year) during the last 5 years. This growth was accompanied with the increase of the number of production items from 54 to 202 as well as of commercial agents from 62 to 130. Furthermore, the company is trying to have more small-sized agents and extend its business to new promising sales sectors such as supermarkets, convenience stores, and large discount stores. Therefore, it is strongly required to improve the logistics chain effectively and efficiently.

In this respect, we focused on the ideal image of the logistics processes in the company <Figure 1>. It shows the whole logistics processes that should be tightly linked each other. Within this scope, we initiated our work on the demand management module because it is where all production and inventory management begins and ends.

The demand management module includes long-term demand forecasting, short-term demand forecasting, and finally demand management outputs. This process is being under development since the management decided to put off its implementation until the other two systems (production planning and inventory systems) have been stabilized. Therefore, we restrict our attention to the latter two systems that will be described in the subsequent sections.

## 3. Computerization of production planning

The production planning process typically begins with an updated sales forecast covering the following years. Any desired increases and decreases in inventory or backlog levels are added or subtracted, and the outcomes form basis of the production plan (Vollman *et al.*, 1993).

The production planning activities in this company are performed only once at the end of the year, so that the next year's monthly-basis quantities of each product are the outcomes. The activities seem to be so inflexible that the outcomes are never changed, and even never referenced at all during the whole year. They are only for the report's purpose to the top management at the beginning of new fiscal year. We concluded that this is caused by the fact that these activities are performed by manual, consequently, it takes about 3 to 4 weeks for the whole planning department to finish the job.

Computerization of the production planning activities is proposed. A linear programming (LP)

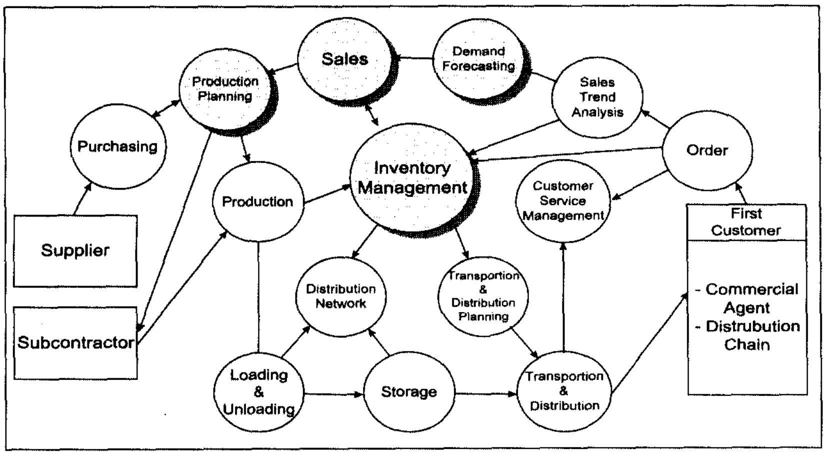


**Figure 1.** Logistics processes.

methodology with user-friendly I/O interfaces such as Visual Basic is the promising alternative. An attempt is made to exempt the model operators from understanding the whole LP equations in detail, since many mathematical models hard to understand tend to be obsolete so early (Yang *et al.*, 2002). Modeling the production line using LP is rather straightforward and manageable because each production line is mostly dedicated to a group of items and it requires a given number of workers whatever the items it may produce.

The time horizon of production planning process on a monthly- basis is depicted in <figure 2>.

Through computerization of the process, it can provide the production department with the monthly production plan within several minutes, and further the department can make use of the planning outcomes at every month. This, in turn, activates the planning functions to flexibly respond to the changing market conditions and to closely be coordinate with the inventory process.

The following notation is used in the production planning model presented in this section. Input parameters that are to be provided by users are written in bold.

J : set of items produced($J_1$ ,by workers and facilities) or assembled only($J_2$, by workers without using any facilities) in a factory

$X_{ijkl}$ : Production hour of $i^{th}$ month for j ($\in J_1$) item of size $l$ at $k^{th}$ line

$Y_{ijkl}$ : Manhour of $i^{th}$ month for j ($\in J$) item of size $l$ at $k^{th}$ line

$RI_{ijl}$ : Reserved Inventory Quantity of $i^{th}$ month for j item of size $l$ ( box/month)

$TMT_{ik}$ : Net Total Production hour of $i^{th}$ month at $k^{th}$ line (= $MWD_{ik}$ * $DT_{ik}$ * $E_{ik}$)

$MWD_{ik}$ : Monthly Working Day of $i^{th}$ month at $k^{th}$ line

$DT_{ik}$ : Production Time in a Day of $i^{th}$ month at $k^{th}$ line

$E_{ik}$ : Production Efficiency of $i^{th}$ month at $k^{th}$ line (real number, 0 < E < 1)

$S_{ijl}$ : Production (Assembly) Quantity (box/month) of $i^{th}$ month for j item of size $l$

$$= \begin{cases} \sum_{k \in K} P_{jkl} * R_k * X_{ijkl} & if\ j \in J_1 \\ \sum_{k \in K} P_{jkl} * R_k * Y_{ijkl} & if\ j \in J_2 \end{cases}$$

K : set of lines which produce the same item

$P_{jkl}$ : Production(Assembly) Quantity per hour (box/hour) for j item of size l at $k^{th}$ line

$R_k$ : Net Production(Assembly) Rate (real number, 0 < R < 1)

$DE_{ijl}$ : Demand Quantity (box/month) of $i^{th}$ month for j item of size $l$

$AP_{ks}$ : Assigned persons for $k^{th}$ line of s (integer)

$TMM_{is}$ : Total man hours of s in $i^{th}$ month (integer)

$$s = \begin{cases} 1, & if\ sex = male \\ 0, & otherwise \end{cases}$$

$\alpha_i$, $\beta_i$, $\gamma_i$ : weights of production hours, man hours, and the reserved inventories, respectively

The objective of the model is to minimize the weighted sum of production hours, man hours, and the reserved inventories;

Minimize

$$\sum_{i,j,k,l} \{\alpha_i X_{ijkl} + \beta_i Y_{ijkl}\} + \sum_{i,j,l} \gamma_i RI_{ijl} \quad (1)$$

*s.t.*

$$\sum_{j \in J_1, l} X_{ijkl} \le TMT_{ik} \quad \text{for all i, k} \quad (2)$$

$$S_{ijl} + RI_{ijl} \ge DE_{ijl} + RI_{i+1jl} \quad \text{for all i, j } (\in J_1), \text{k}, l \quad (3)$$

$$\sum_{j,k,l} \{AP_{ks} * Y_{ijkl}\} \le TMM_{is} \quad \text{for all i, s} \quad (4)$$

$$Y_{ijkl} \ge X_{ijkl} \quad \text{for all i, j, k}, l \quad (5)$$

Constraint (2) imposes the available production hours per line in every month. Constraint (3) ensures production quantities of each item of each size are greater than or equal to the sales forecast and if it cannot be met, the reserved inventory is to be held. Constraint (4) imposes the available working hours of men and women in every month. Consistency is imposed by constraint (5). About 7200 variables and 3700 constraints were employed to solve twelve-month production plan. Integer property of each variable has been relaxed for the sake of CPU times.

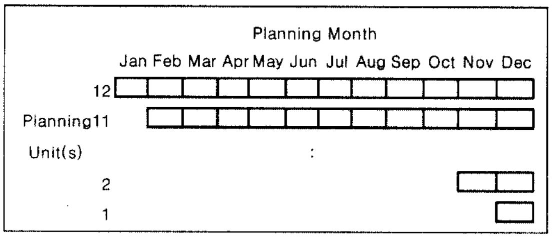


**Figure 2.** Time horizon of production planning.

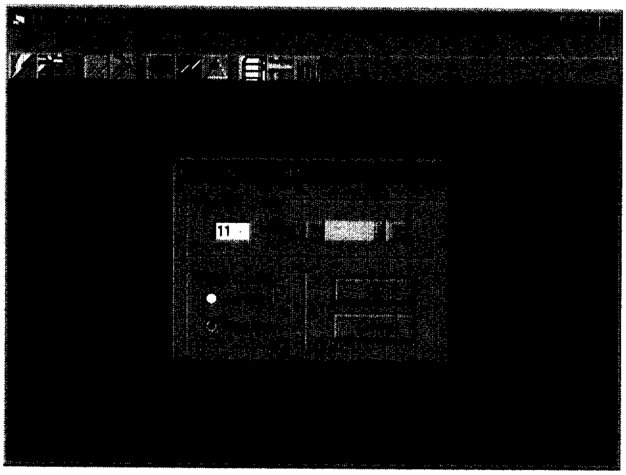

Figure 3. Initial Screen.

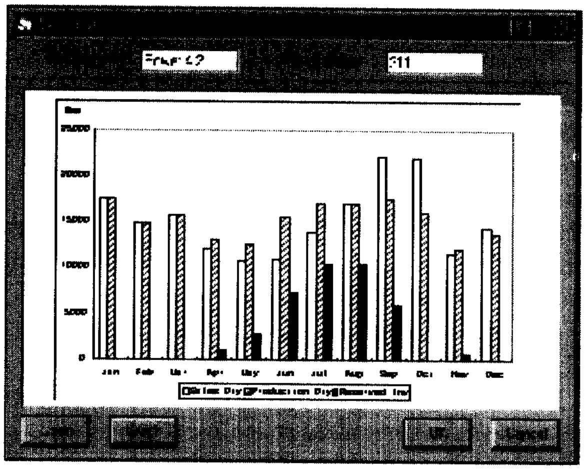

Figure 5. Output Screen.

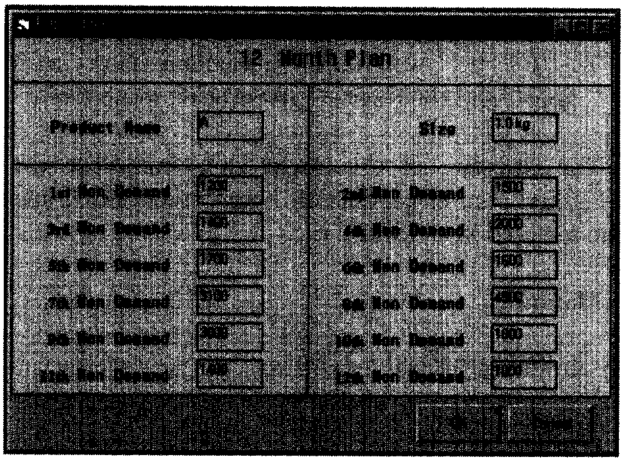

Figure 4. Input Screen.

The I/O interface module is written in Visual Basic 4.0. Parts of input screens are shown in <figure 3> and <figure 4> and a summary of output is depicted in <figure 5>.

## 4. Statistical inventory control

A company's inventory investment which enables us to efficiently produce goods at some distances from the actual customer is heavily influenced by not only strategic but operational decisions made in the other areas (Vollman *et al.*, 1993). For example, assuming the sales forecasting and inventory control ability is maintained at some level, higher targets for customer service will increase inventory investment. Likewise, a program to reduce equipment changeover times can dramatically reduce inventory investment.

Top management's view of the inventory in his company could be abbreviated as follows; Reduce the inventory as much as possible AND increase the fill-rate up to 100% This request is rather absurd theoretically and practically. We took much time for the management to recognize the relationship between the inventory level and the fill-rate. We persuaded them to strategically determine the fill-

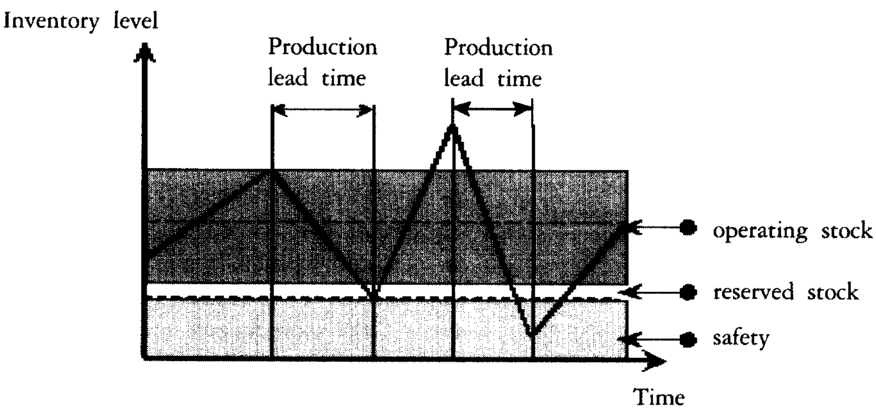


Figure 6. inventories concept.

rates of each group (A, B, or C) of items and then to ask the relating departments to have the minimum required inventory level at the given fill-rate. Also, we strongly recommended that the most important thing to reach the reasonable inventory level is their continuous and careful watch.

In this sense, we proposed the reasonable inventory levels of each item which can be statistically calculated using historic data of the items, and are composed of safety stock from the given fill-rate, operating stock from the production patterns, and reserved stock from the production planning. Safety stock can be defined as the inventory prepared for the production variation as well as sales variation, and could be approximately expressed as

$$Z_\alpha \cdot \sqrt{\mu_{pt}\left(\sigma_p^2 + \sigma_s^2\right) + \mu_s^2 \cdot \sigma_{pt}^2} \qquad (6)$$

where $Z_\alpha = (1-\alpha)$ percentile in standard normal distribution, $\mu_{pt}$ = mean production lead time, $\sigma_{pt}^2$ = production lead time variance, $\mu_s$ = mean daily sales, $\sigma_s^2$ = daily sales variance, and $\sigma_p^2$ = daily production variance. Operating stock occurs inevitably when production lines are running while reserved stock is generated in the production planning module for peak time demand, holiday season demand, and so on. <Figure 6> depicts the inventories defined here.

An emphasis should be placed on the fact that the calculated values of an inventory level may be even meaningless, and setting a level item by item, whatever the level it may be, could be a big step toward controlling the inventory. This strategy turned out to greatly reduce the total inventories(See <Figure 8>).

## 5. Integration of production planning and inventory management, and its application

The image of integration of production planning and inventory management in the company is shown in <Figure 7>.

It describes how the production planning and inventory management is coordinated and what is included in the processes. <Figure 8> shows the total inventories that have been reduced significantly even though the sales amounts have been on the increase.

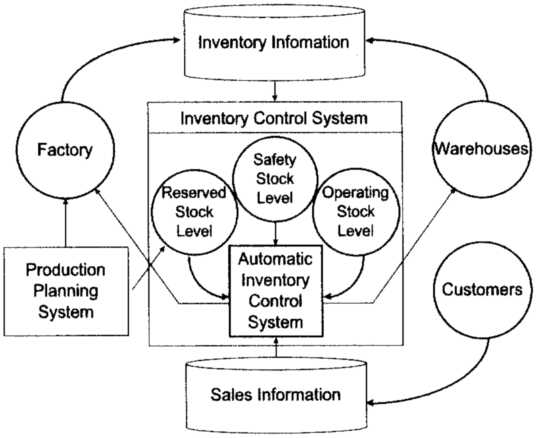


**Figure 7**. Image of integration.

## 6. Conclusion

In this study, an integrated model of production planning and inventory has been developed. The

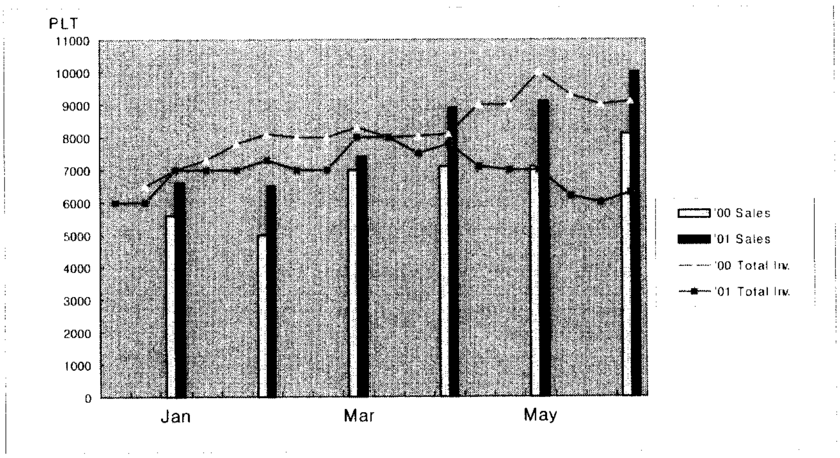


**Figure 8**. Total inventory reductions.

demand management modules include long-term demand forecasting, short-term demand forecasting, and finally demand management outputs. This process is being under development since the management decided to put off its implementation until the other two systems (production planning and inventory systems) have been stabilized.

Computerization of the production planning activities is proposed and implemented. Modeling the production line using LP is rather straightforward and manageable because each production line is mostly dedicated to a group of items and it requires a given number of workers whatever the items it may produce. We also proposed the reasonable inventory levels of each item which can be statistically calculated using historic data of the items, and are composed of safety stock from the given fill-rate, operating stock from the production patterns, and reserved stock from the production planning. The proposed system will be best fitting where more than hundreds items are produced in flow production lines and there are heavy logistic traffics and flows.

This study has helped the firm to have clearer job definition of the related processes, to tightly control the inventory by setting and tracing the reasonable fill rates for every product, and to quickly respond to the market changes through the computerized production planning process.

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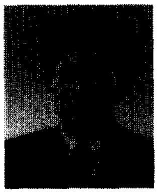


**안 재 경**
서울대학교 산업공학과 학사
서울대학교 산업공학과 석사
University of Iowa 산업공학과 Ph.D.
현재: 서울산업대학교 산업정보시스템공학과 부교수
관심분야: 공급체인관리, 통신서비스 기술경제성평가, 기업가치평가 등