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Management of Reasonable Inventory Level for Environmentally-friendly Corporate Productive Activities

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Abstract

In the production management which changes suddenly in industry, in order to correspond to a customer's needs quickly, a company always has to secure many stock. Therefore, it is needed that a company cuts down waste such as extra stock and physical distribution cost in supply chain network. This leads to reduct of environmental load. One of main reason which requires large stock is bullwhip effect. So, mechanism of supply chain management to reduce bullwhip effect is attracting a great deal of attention. We regard the order from customer to retailer as random variable to consider its fluctuation. Hence, we propose decision support machanism of target inventories which reduce bullwhip effect and a shortage of stock by using evolutionary explorative computing approach.

keyword: Inventory Management, Supply Chain Network, Bullwhip Effect, Evolutionary Explorative Computing

1. Introduction

In recent years, the time manufacturer sells only products which are finished has passed, the time consumers attach importance to diversification and speed has come. In future, the essential condition for winning straight victories market competition is to make a company structure that offers product that a consumer demands as cheaply as possible.

In the economic environment which changes suddenly, in order to correspond to a customer's needs quickly, a company always has to secure many stock. Consequently, increase of the cost in excess stock has big influence on management of a company. On the other hand, it is also important to improve customer satisfaction and consider to environmental load. Therefore, a company cuts down waste such as extra stock and physical distribution cost, and needs a mechanism which send as quickly and cheaply as possible a product. So, supply chain management is attracting a great deal of attention. Therefore, information technology and production system using computer play an important role in earlier time in market.

Now, mass customization is desired (Pine, 1993). It means that a service provider pursues merits of mass production and mass service, as a consumer feels as if a company has dealings individually. For example, in case of automotive manufacturer (Biller, et al., 2001), it says that a customized car is able to extend its specification to three hundred million kinds per one. The customized car has to be manufactured based on order of different specification of consumers. As a result, it leads to decreasing of production efficiency, increasing of finished product stock and dissatisfaction of consumer.

For the problems of mass customization and trends in recent business, diversity of customer satisfaction, globalization of competition and environmental issue and so on can be listed. We think that supply chain management plays important role for such problems. Supply chain spans over multiple companies such as retailers, plants, warehouses and logistics providers. There are studies which are taking up production planning of supplier side (Tayur, et al., 1998, Chopra, et al., 2000). However, in supply chain, it is difficult to coordinate each stage of the supply chain to take into account the impact its actions have on other stages.

The product process is mainly part of a product's life cycle which is made up of the activities that go into making, using, transporting and disposing. The life cycle is commonly shown as a series of stages, from raw material extraction and harvesting, through fabrication, manufacturing, packaging, transportation, consumption, and recycling, to the disposal. The environmental problems associated with a product can be traced back to the inputs that go into the product such as land, materials, water, energy, and the outputs generated, for example, air emissions, liquid effluents, solid wastes, at each stage in manufacturing. It is very important to manage production planning to minimizing the environmental burdens associated with manufacturing wastes.

One of fundamental challenge is to achieve coordination in spite of multiple stages and increase product variety by avoiding bullwhip effect. Bullwhip effect is phenomena such as the increasing amplification of orders occurring whithin supply chain the more one moves upstream (Chen et. al., 2000). We define production planning and management system as the stochastic programming problem. To solve such problems, we focus on material flow, because determination of orders for proper logistics and stock is the most important factor affecting overall supply chain network. In this paper, we will propose application of evolutionary explorative computing approach to inventory management for reducing bullwhip effect in supply chain.

2. Inventory Management in Supply Chain Network

Recently, the word, supply chain management, is frequently heard. It becomes a household word as scientific vocabulary these days, and comes into use on television advertisement and news. The manager in supply chain network purchases parts and raw materials, and produces goods, and sells it through wholesaler and retailer. This flow : parts and raw materials traders → manufacturers → wholesaler → retailer is called supply chain management. Supply chain management attempts to optimize stocks and tries to maximize its own profits. Note that the aim of supply chain is the total optimization. Because, it is known that repeating sub-optimizations do not always bring the total optimization.

In the manufacturing industry, stocks mean inventory of parts, partly-finished product, work-in-process inventory, stock of finished goods and so on. When a manager optimizes the stock, he must take account of the stock of not only manufacturer but also parts and raw materials traders, wholesaler and retailer. Generally, items are sent to end demand person from a supplier through the production and the circulation process of many stages (Stadtler et. al., 2004). The flow of supply chain in automotive industry is shown in Figure 1.

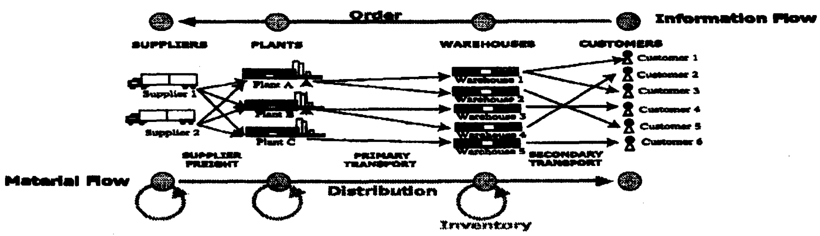

Figure 1: Material and information flows in supply chain

In the aim of holding inventories to a minimum in supply chain, the prediction of demand is very important. It uses mainly a data which a store collected and analyzed, for example performance in selling. After the predicted data is reported a shop and manufacture sequentially as a purchase estimate, each step in supply chain controls production and stock. The manufacturer can make beforehand production planning and delivery planning by the use of predicted data. Since a manager provides information on needed volume of raw material to each supplier in advance, he can provide infallibly the needed goods in a timely fashion. In this way, because each player who participates in supply chain shares information, lead-time between procurement of raw material and consumer can is reduced. And, it can eliminate the waste such as extra stock and physical distribution cost. Conclusively, the goods come to be rapidly delivered consumer at a low price. It is thought that consumer causes demand for one retailer (Chen et. al., 2000).

Therefore, it is necessary to provide 100% services to its customers with the base stock which satisfies the above requirement with the least inventory. For the purpose of holding the base stock down and shortening service time to its customers, the optimization problem has been formally formulated (Graves, et. al., 2000).

[Formulation of adequate stock problem]

$$\min \sum_{\gamma \in \Gamma} h^\gamma J^\gamma \tag{1}$$

$$s.t.\quad J^\gamma = D^\gamma(LI^\gamma + PT^\gamma - L^\gamma) - (LI^\gamma + PT^\gamma - L^\gamma)\mu^\gamma \quad (\forall \gamma \in \Gamma), \tag{2}$$

$$L^\gamma \leq LI^\gamma + PT^\gamma \quad (\forall \gamma \in N_\gamma), \tag{3}$$

$$L^\gamma \leq LI^l \quad (\forall \gamma \in A, \forall l \in \Gamma), \tag{4}$$

$$L^\gamma \geq 0 \quad (\forall \gamma \in \Gamma), \tag{5}$$

$$LI^\gamma + PT^\gamma - L^\gamma \leq L^\gamma_{max} \quad (\forall \gamma \in C). \tag{6}$$

The notations are used for the following meaning.

h^γ : Per-unit holding cost for inventory at stage γ
PT^γ : Production lead-times
J^γ : Safty stock at stage γ at the end of period
$D^\gamma(\tau)$: Demand process at stage γ
μ^γ : Average demand per time period
LI^γ : Maxmum of guranteed lead time at stage γ
Γ : Set of stages
A : Index set representing the relationship among stage
N^γ : Index set relating to stage γ
C : Set of index which has lead time constraint
L^γ_{max} : Upper bound of lead time at stage γ

Assume that demand for end item j is normally distributed with mean μ and standard deviation σ at each period. Eq. (6) is introduced by considering limit of inventory (Yamaguchi, et. al., 2006). In order to position safety stock, the condition of demand bounds is as follows at the stage j.

$$D^\gamma(\tau) = \tau\mu^\gamma + k\sigma^\gamma\sqrt{\tau} \tag{7}$$

where, k is the safety stock which covers the demand variation some percentage of time.

3. Production Lead-times by Production Planning

The stock management is executed to satisfy demand of consumer by keeping enough volume of goods. It is very important in business finance. Nowadays, it says that 25% of the value of goods in stock is inventory carrying costs. The usual production management system makes production planning based on prediction, raises operation rates and production capability, maximizes cost per performance. As a result of the efficiency of productive process, it comes to lead to better productivity and increase profitability. However, even if this approach is useful for the efficiency of productive process, it may not be correct selection for increasing of profitability. In case that there are a lot of fluctuation factors and distinct elements, the accuracy of prediction value is limited. That is, since the plan made based on prediction is not absolute, the scenario which contributes increasing of profitability may not be useful for total supply chain. The true goal is not the improvement in productivity but the increasing of profitability.

A manager should not make plan based on only the past data. In the business process connecting with customer, supplier and partner, a manager can gain demand data at real time. Because the selected scenario which contributes increasing of profitability is being carried out, there is some possibilities until achieving true goal. For example, when certain parts in upper process are used to produce various goods in lower process, the quantity of production per time of these goods in lower process must get agreement with the sum of the quantity of production per time of parts in upper process. However, if a plan in processes increases, the capacity balance between both processes may collapse and excess or shortage may arise in middle stock (Muramatsu, et. al., 2003).

[Formulation of production scheduling problem]

$$\min \sum_{i\in I}\sum_{t\in T}\{\sum_{k\in K(i)} c_i^k(1-\delta_{it-1}^k)\delta_{it}^k + h_i x_{it}\} \tag{8}$$

$$s.t. \quad x_{it} = x_{it-1} - r_{i\cdot t} + \sum_{k\in K(i)} p_i^k \delta_{it}^k I(s_{it}^k) \tag{9}$$

$$s_{it}^k = s_{imax}^k(1-\delta_{it-1}^k)\delta_{it}^k + [s_{it-1}^k - 1]_+ \delta_{it-1}^k \delta_{it}^k \tag{10}$$

$$\sum_{j\in S(i)} \rho_{ij}(x_{jt} - x_{j0}) - \sum_{t'=1}^{t}(r_{j\cdot t'} - r_{j0t'} - \sum_{j\in S(i)} \rho_{ij} r_{j\cdot t'}) - x_{it} \le 0 \tag{11}$$

$$\sum_{i\in M(k)} \delta_{it}^k \le 1 \tag{12}$$

The notations are used for the following meaning.

c_i^k : Set up cost for item i at machine k
δ_{it}^k : Control variables
h_i : Holding cost of item i
x_{jt} : Inventory of item j at end of period t
r_{ijt} : Requested order
p_i^k : Productivity per unit time for item i at machine k
$I(x)$: Index function
s_{imax}^k : Set up time for item i at machine k
s_{it}^k : Remaining time of set up
$K(i)$: Set of machine which handles item i
$M(k)$: Set of item which is handled by machine k
$S(i)$: Set of tariling item of i

We assume that the requested order quantity $r_{ijt} = \rho_{ij} r_{j\cdot(t-L_{ij})}$ and $r_{i\cdot t} = \sum_{j\in S(i)} r_{ijt} + r_{i0t}$. L_{ij} denotes guranteed lead time of item i for item j. δ_{it}^k takes 1 when it is in process, otherwise 0. $I(x)$ takes 1 when it is equal to 0, otherwise 0. ρ_{ij} takes 1 when it satisfies $i \in B$ and $j \in S(j)$, otherwise 0. B denotes set of item in process. The parts which are used to produce certain goods may be used to produce others. And, since a manager derives about three hundred million patterns of production from one specification, he must choose proper goods and produce it for a consumer. Therefore, the stock management is one of most important factor of physical distribution system because the stock holds majority in capital investment. There are positive aspects such as a margin of customer service and production planning. On the other hand, there are down sides : the fixation of capital fund, the increase in carrier charge, the obsolescence or wastage for a term of stock, the block of the flexibility of administrative action. That is, the maintenance of proper stock is very important subject of study.

For example, the auto manufacturer hold and manage almost all parts in order to repair vehicle in one's product. The kind of parts which a manager supplies a detail shop is about half a million because of addition of new model cars. In general, the manufacturer has a parts center which can purchase, keep and supply these repair parts at real time. There are some patterns in flow of object. Since there are some patterns in flow of object, stock models are divided into some types. One of its standards is the stock point of geographical location. The stock point means the generation point of stock. There are stock points more than one in stock system. In plural stock points, the flow of a manufacture → a wholesaler storehouse → a retailer is typical type. In this paper, we focus on information flow in tree structure model from customer to retailer to wholesaler to factory to supplier.

4. Model Description and Solution Mechanism

We formulate foundamental model which is discussed in this paper. In problem definition and formulation, we consider coefficient of environmental load about inventory such as e_i^γ where i denotes item at stage γ.

Strategic partnerships or information sharing may not work well, under condition of independence among decision making units or difficulty of derivation of order quantity. So we introduce new constraint about minimum of gurantee lead time L_{imin}^γ. We formulate problem deciding the safety stock management J_i^γ for all items and stages as follows;

[Problem for Inventory Management]

$$\min \sum_{\gamma\in\Gamma}\sum_{i\in I}(h_i^\gamma + e_i^\gamma)J_i^\gamma \tag{13}$$

$$\begin{aligned}
s.t.\quad & J_i^\gamma = k_i\sigma_i^\gamma\sqrt{LI_i^\gamma + PT_i^\gamma - L_i^\gamma} && (\forall\gamma\in\Gamma), && (14)\\
& L_i^\gamma \le LI_i^\gamma + PT_i^\gamma && (\forall\gamma\in N_\gamma), && (15)\\
& L_i^\gamma \le LI_i^l && (\forall\gamma\in A, \forall l\in\Gamma), && (16)\\
& L_i^\gamma \ge L_{imin}^\gamma && (\forall\gamma\in\Gamma), && (17)\\
& LI_i^\gamma + PT_i^\gamma - L_i^\gamma \le L_{imax}^\gamma && (\forall\gamma\in C). && (18)
\end{aligned}$$

In problem definition and formulation, we consider coefficient of environmental load about machine process such as $e_{it}^{k\gamma}$ where i denotes item at machine k at period t on stage γ. We formulate problem estimating the production lead time PT_i^γ and variance of requested order σ_i^γ which satisfies minimizing cost of total supply chain as follows;

[Problem for Production Lead Time]

$$\min \sum_{\gamma\in\Gamma}\sum_{i\in I}\sum_{t\in T}\{\sum_{k\in K(i)} c_i^{k\gamma}(1-\delta_{it-1}^{k\gamma})\delta_{it}^{k\gamma} + e_{it}^{k\gamma}\delta_{it}^{k\gamma}\} \tag{19}$$

$$s.t.\quad x_{it}^\gamma = x_{it-1}^\gamma - r_{i\cdot t}^\gamma + \sum_{k\in K(i)} p_i^{k\gamma}\delta_{it}^{k\gamma}I(s_{it}^{k\gamma}) \tag{20}$$

$$s_{it}^{k\gamma} = s_{imax}^{k\gamma}(1-\delta_{it-1}^{k\gamma})\delta_{it}^{k\gamma} + [s_{it-1}^{k\gamma} - 1]_+\delta_{it-1}^{k\gamma}\delta_{it}^{k\gamma} \tag{21}$$

$$\sum_{j\in S(i)} \rho_{ij}^\gamma(x_{jt}^\gamma - x_{j0}^\gamma) - \sum_{t'=1}^{t}(r_{j\cdot t'}^\gamma - r_{j0t'}^\gamma - \sum_{j\in S(i)}\rho_{ij}^\gamma r_{j\cdot t'}^\gamma) - x_{it}^\gamma \le 0 \tag{22}$$

$$\sum_{i\in M(k)} \delta_{it}^{k\gamma} \le 1 \tag{23}$$

The production lead time PT_i^γ is given by

$$PT_i^\gamma = \frac{1}{W}\sum_{w=1}^{K} R_{PT_i^\gamma}^w \tag{24}$$

where $R_{PT_i^\gamma}^w$ is production time about wth production of item i, which is estimated by solving problem about production scheduling. W denotes number of total production of item i. The variance of requested order σ_i^γ is derived from

$$\sigma_i^\gamma = \mathrm{E}[{r_{i\cdot t}^\gamma}^2] - \mathrm{E}[r_{i\cdot t}^\gamma]^2 \tag{25}$$

[Algorithm]

Step 1
Give the gurantee lead time L_i^γ, and solve the problem about production lead time.

Step 2
Estimate the production time $R^w_{PT_i^\gamma}$, then calculate the production lead time PT_i^γ and the variance of requested order σ_i^γ.

Step 3
Solve problem for inventory management, then derive the optimal lead time L_i^γ and the safety stock J_i^γ.

Step 4
If the lead time derived by Step 3 converges to almost same value then iteration is finished, otherwise go to Step 1.

5. Concluding Remarks

The purpose of supply chain management, it attempts to optimize stocks and tries to maximize its own profits. In this paper, we took up reduction of inventory in supply chain management. We proposed dynamics which presented a modification version of basic model of safety stock considering production scheduling. For the total supply chain from customer to wholesaler to factory to supplier, the optimization problem was formulated. Derived target inventory by solving the optimization problem leads reduction of safety stock. We finally proposed the mechanism to solve the optimization problem in approximation. Further work is system development which includes proposed mechanism for the total supply chain management.

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