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Integration of Delivery Policy and Application of Multiple Objective Decision Method－A Supply Chain Collaboration Approach

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ABSTRACT

Few previous researches have considered the integration of three echelons, which is the central focus of this paper. This study focuses specifically on the decisions of frequent deliveries of an order, under a three-echelon distribution system of multiple manufacturers, one distribution center (DC), and several retailers. The authors develop a fully-integrated model by multiple objective decision making method. The main goal is to find solution of the model which optimizes both objectives functions simultaneously. In addition, typical partial-integrated model is defined as quantity of products by which manufacturers produced and transported according to the result that achieves the minimum total cost of the DC and the retailers. Compared with fully-integrated model, the total relevant cost is significantly less than the total cost of a typical partial-integrated policy. The results of this study indicate that companies should consider the changes necessary to support fully integration; the total relevant cost within the supply chain can be significantly reduced when compared with a typical partial-integration.

Keywords: Supply Chain Management, Multiple Objective, Integration, Distribution Center, Three Echelons

INTRODUCTION AND LITERATURE REVIEW

Faced with strong competition, manufacturing firms are now attempting to look for different ways to improve their operations, reduce costs, and increase the profitability of their businesses. In general, the relationship of a buyer and the supplier has been characterized in the literature in terms of cooperative versus competitive relationships (Choi, Wu, Ellram, and Kola 2002). Both purchaser and vendor may benefit from negotiation and the two sides must determine jointly how to divide the savings (Thomas and Griffin, 1996). The customer firm can benefit from an improvement in the buyer-supplier relationship (Wagner, 2006).

A product is delivered to the end customer through a supply chain of firms, which consists of suppliers, manufacturers, and distributors. Thus, a manufacturer cannot be responsive without satisfied suppliers, and the benefits of such a relationship cannot be transferred to the end customer unless the distributors align with this manufacturer's strategy as well (Bentona and Malonib, 2005).

Transnational transport service provider understands the importance of global logistics gradually. The third party logistics (3PL) successes in creating and managing all logistics activities, and makes the logistics network can prosper the prosperity on the market. In the past 10 years, manufacturing industries of U.S.A. generally accept the concept of third party's logistics. The logistics transport service provider is integrating continuously. Supply chain includes supplier, manufacturer, transport service provider, distribution center, and retailer establish long-term partnership or alliance's relationship. They take responsibility and share profits together during agreement period.

The retailers often sell many kinds of goods which come from a lot of different suppliers. If they lack efficient delivery planning, not only will the freight increase, but the personnel cost will go up and seriously influence the operation because of the delivery and unloading of numerous suppliers. Losses will also be difficult to assess.

Traditionally, enterprises utilize the storage operation system to manage inventory and the suppliers transport the goods to a distribution center (DC). The products are classified, consolidated, and stored. Products can be delivered to the retailers to meet customer demand from the DC as long as a retailer sends out the order. Although they can meet a retailer's demand quickly, the stock costs of enterprises increase by storing goods.

The analysis and design of production-distribution systems has been an active area of research for many years. Another body of research considers the problem of coordinating two different functions of the system. To date there exist little research that addresses the linkage of the two integrated model.

Yılmaz and Catay (2006): A production–distribution system is referred to as an integrated system consisting of various entities that work together in an effort to acquire raw materials, convert these raw materials into specified final products and deliver these final products to markets. They address a strategic planning problem for a three-stage production–distribution network. The objective is to minimize the costs associated with production, transportation, and inventory as well as capacity expansion costs over a given time horizon.

Collaboration across the supply chain (Chung and Leung, 2005), especially multi-echelon distribution systems (Van Houtum, Inderfurth, and Zijm, 1996) have been of wide concern since they meet the demand of application. Most of the studies have explored the two echelons of buyer-vendor systems (Chandra and Fisher, 1994; Barbarosoglu, 2000; Bylka, 2003). Chandra and Fisher were among the first to study the integrated production-distribution planning problem.

Several other studies have considered an enriched version of the models which use multiple deliveries of an order (Lu, 1995; Aderohunmu, Mobolurin, and Bryson, 1995; Goyal, 1988, 2000; Hill, 1999; Kelle, Al-khateeb, and Miller, 2003). These models considered multiple deliveries of an order, but they did not emphasize the logistics center as a medium, in order to reach the purpose of both parties making large batches and transporting in turn. Kreng and Wang (2005) suggested that manufacturers can optimize their total cost by deciding whether or not to cooperate with third party logistics (3PL) and arrive at their optimal production lot size. 3PL will also occupy a much more important position in the JIT system under a global supply chain.

In this study, the above model is extended to construct a three echelon supplier-buyer relationship that uses a distribution center as an intermediary. The proposed three-echelon system consists of multiple manufacturers, one distribution center, and multiple retailers. Because of the joining of logistics center, the manufacturers can achieve dominance with large-scale production and shipment and the buyer can achieve dominance with small and frequent shipments.

The development of the integrated model is suitable for either independent JIT system or profit centers from the main office. They emphasize the minimum cost and pay attention to the reducing of the total cost of system at the same time. While considering the situation of profit centers, reducing of the total system cost will be more significant than the importance of any specific party’s cost (Kreng and Chen, 2007).

In this study, a three-echelon coordinated model is illustrated. In the next section, we decouple the model into production and distribution scheduling sub-models. The sub-model of production scheduling coordinates the manufacturers and the distribution center. Another sub-model of distribution scheduling coordinates the distribution center and retailers. Multiple deliveries of an order and the quantity of shipment can satisfy the quantity-periodic demand of retailers under the prerequisite of not increasing freight charges. In addition, the fully-integrated model and partial-integrated model are discussed, respectively. Finally, the computational results and the related conclusions are addressed.

MATHEMATICAL MODELS

In the problem we considered, several products are produced over time in multiple factories. The products of different factories are stored and consolidated by the distribution center (DC) and are delivered to a number of retailers. This study aims to schedule production and distribution so as to highlight the performance of coordination model.

The production lot size of the manufacturer is scheduled to be produced and delivered to the DC in M shipments. Then, the DC matches the JIT demand from the retailers to dispatch them.

Rationale of The Model：Assumptions and Notation

In this study, a period t is subdivided into V smaller periods (e.g. one period represents for one month, therefore, it contains 30 days (smaller period units)). Customer demand for each product in every smaller period was an integer generated independently from normal distribution. All parties in this study share the demand information; thus, the demand for each product in every smaller period at the retailers is known and this study assumes the total demand of each product of the retailers is fixed based on aggregate demand (Xu and Evers, 2003). Each product had identical processing time per unit and used an identical amount of vehicle capacity per unit. Retailers’ replenishment cycles were assumed to be the same. Each manufacturer's productivity is similar to the others. In addition, the authors suppose that shortage is not allowed.

Manufacturers focus on large-scale production and retailers require more frequent delivery with small batches. The distribution center has been incorporated to function as an inventory storage point; therefore, the number of shipments from the DC to retailers is greater than the number of shipments from the factory to the DC. We assume that $[\alpha]$ denotes the largest integer not greater than α. The following notations have been adopted.

Variables:

x_{kjtm}	Actual production and delivery lot size of product *j* of factory *k* to the DC for m^{th} shipment in period *t*
y_{kjtm}	1, if the product *j* of factory *k* must be set up for m^{th} shipment in period *t* 0, otherwise
z_{kjtm}	Quantity of product *j* of factory *k* is delivered to the DC for m^{th} shipment in period *t*
q_{kjtn}	Quantity of product *j* of factory *k* is delivered to retailers for n^{th} shipment in period *t*
M	Number of shipments per order from factory to the DC ($1<M<N$)
N	Number of shipments per order from the DC to retailers
τ	$=[\frac{N}{M}]$ (denotes the largest integer not greater than $\frac{N}{M}$
r_{tn}^{1}	Number of direct trips from the DC to retailers for n^{th} shipment in period *t*
r_{ktm}^{0}	Number of direct trips from factory *k* to the DC for m^{th} shipment in period *t*
I_{kjtm}^{0}	Inventory of product *j* of factory *k* at the DC for m^{th} shipment in period *t*
I_{kjtn}^{1}	Inventory of product *j* of factory *k* at the DC for n^{th} shipment in period *t*
I_{kjtn}^{i}	Inventory of product *j* of factory *k* at retailers for n^{th} shipment in period *t*

Parameters:

T	Number of time periods.
F	Number of factories
R	Number of retailers
V	Number of smaller periods of a period ($=\lambda N$, λ is an integer)
J_k	kind of products of factory *k*.
d_{kjtn}	Demand for product *j* of factory *k* at retailers for n^{th} shipment in period *t*.
$d_{kjtv}^{'}$	Demand for product *j* of factory *k* at retailers in a smaller period *v* in period *t*.
C_1	Capacity of each delivery vehicle from the manufacturer to the distribution center.
C_2	Capacity of each delivery vehicle from the distribution center to the retailer.
s_{kj}	Fixed setup cost incurred for product *j* of factory *k*.
h_{kj}^{1}	Inventory holding cost per unit of product *j* of factory *k* per period of shipment at the DC.

h_{kj}^{i}	Inventory holding cost per unit of product *j* of factory *k* per period of shipment at retailers.
c^{1}	cost of direct travel from the DC to the retailers
c^{0}	cost of direct travel from factory to the DC

The total cost of the system includes the total cost of production setups, transportation, and holding inventory can be determined as follows:

$$TOT = \sum_{t=1}^{T}\sum_{k=1}^{F}(Q_{kt} + H_{kt}) + T$$

where T= $\sum_{t}^{T}\sum_{n}^{N} c^{1} r_{tn}^{1} + \sum_{t=1}^{T}\sum_{k=1}^{F}\sum_{m=1}^{M} c^{0} r_{kmt}^{0}$ the former denotes transportation cost which is from the DC to the retailers, and the latter is from the manufacturer to the DC.

$Q_{kt} = \sum_{j=1}^{J_k} s_{kj} y_{kjmt}$: denotes the manufacturer's setup cost, and

$H_{kt} = \sum_{m=1}^{M}\sum_{j=1}^{J_k} h_{kj}^{0} I_{kjtm}^{0} + \sum_{n=1}^{N}\sum_{j=1}^{J_k} h_{kj}^{1} I_{kjtn}^{1} + \sum_{n=1}^{N}\sum_{j=1}^{J_k} h_{kj}^{i} I_{kjtn}^{i}$: denotes the holding inventory costs of the DC and the retailers. I_{kjtm}^{0} : denotes stock happening because of producing ahead of time. In order to minimize total relevant cost, when setup cost is larger than holding inventory cost, the product j of factory k does not be set up for mth shipment in period t; that is y_{kjtm} =0, and they were set up , produced and delivered in the previous period. Therefore, the stock, I_{kjtm}^{0} , happens. I_{kjtn}^{1} : denotes inventory of product j of factory k for nth shipment in period t; that is, stock happens because of matching and transporting in turn to retailers from the DC. I_{kjtn}^{i} is stock of the retailers.

Our model consists of two stages, which we denote by (DS) and (PS). In the first stage, the distribution center and the retailers are integrated. In the second stage, the manufacturers and the distribution center are integrated. The algorithms employed for each of these problems are described below in separate subsections.

Distribution Scheduling

According to convention, the more frequent deliveries buyers make in an order, the more substantially the buyer's stock can be reduced. However, freight charges will increase. Therefore, we expose distribution scheduling and integrate the distribution center and retailers. Minimizing the freight charges and retailers' stock cost is the main goal.

The amount $\sum_{k=1}^{F}\sum_{j=1}^{J_K} q_{kjtn}$ of product j of factory k is delivered to retailers for the n^{th} shipment in period t is in general divided between full loads and partial loads (Chandra, & Fisher, 1994). In order to meet a buyer's demand, the product for the partial load that can be shifted from the nth shipment to $(n\text{-}1)^{th}$ shipment is determined. Although stock costs increase slightly, total freight charges do not increase.

We assume that Q full truck loads of goods, where Q= $[\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2]$, will be delivered to retailers on the nth shipment in period t. The partial load, $\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2 - [\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2]$, is merged into the previous shipment. In order to reduce holding inventory cost, the products with a lower inventory unit cost are arranged to the partial load.

First, the total quantity of full truck load goods, w_{tn}, that can be delivered to retailers from the DC for the nth shipment in period t is calculated using $w_{tn} = C_2[\sum_{k=1}^{F}\sum_{j=1}^{J_K} d_{kjtn}/C_2]$ ([α]: denotes the largest integer not greater than α) for all $t=1,\ldots,T$ and $n=N, N\text{-}1,\ldots, 1$. When $\sum_{k'j'} d_{k'j'tn} \le w_{tn}$, the shipment amount of each product, $q_{k'j'tn}$, is equal to demand quantity, $d_{k'j'tn}$. Note that if $\sum d_{k'j'tn} \le w_{tn}$, and $\sum d_{k'j'tn} + d_{kjtn} > w_{tn}$, the shipment quantity of the product is adjusted as $q_{kjtn} = w_{tn} - \sum d_{k'j'tn}$. The remaining products $\delta_{kjtn} (= d_{kjtn} - q_{kjtn})$ are shifted to the previous shipment. Therefore, the demand of the previous period is adjusted as $d_{kjt(n-1)} + \delta_{kjtn}$.

The remaining products, δ_{kjnt}, to be delivered as a partial load and delivered together with other goods in a previous shipment, which is the central focus of this sub-model. r_{tn}^1 is the number of direct trips from the DC to retailers for *the* n^{th} shipment in period *t*, and the transportation cost from the DC to retailers is $\sum_{t}^{T}\sum_{n}^{N} c^1 r_{tn}^1$ in period *t*.

The objective function represents the cost functions, including the transportation cost from distribution center to retailers, and the inventory holding cost(H_{kt}) of retailers and DC.

$$\text{Min} \quad TOT_1 = \sum_{t=1}^{T}\sum_{k=1}^{F} H_{kt} + \sum_{t}^{T}\sum_{n}^{N} c^1 r_{tn}^1 \tag{DS}$$

where $H_{kt} = \sum_{m=1}^{M}\sum_{j=1}^{J_k} h_{kj}^0 I_{kjtm}^1 + \sum_{n=1}^{N}\sum_{j=1}^{J_k} h_{kj}^1 I_{kjtn}^1 + \sum_{n=1}^{N}\sum_{j=1}^{J_k} h_{kj}^i I_{kjtn}^i$

Subject to

$$I_{kjtv}^i = I_{kjt,v-1}^i + q_{kjtn} - d_{kjtv}^{'} \quad for \quad all \quad k,j,t,n,v = 1, \ 1+\lambda, \ 1+2\lambda,...,1+(N-1)\lambda \tag{2.1}$$

$$I_{kjtv}^i = I_{kjt,v-1}^i - d_{kjtv}^{'} \quad for \quad all \quad k,j,t,v = 2,3,4,...,\lambda,\lambda+2,...,2\lambda,2\lambda+2,...,V \tag{2.2}$$

$$r_{tn}^1 = [\sum_{k=1}^{F}\sum_{j=1}^{J_K} q_{kjtn} / C_2] \quad for \quad all \quad n = N, N-1,...,2 \tag{2.3a}$$

$$\left.\begin{aligned} r_{tn}^1 &= [\sum_{k=1}^{F}\sum_{j=1}^{J_K} q_{kjtn}/C_2] \quad if \quad \sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2 = [\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2] \\ &= [\sum_{k=1}^{F}\sum_{j=1}^{J_K} q_{kjtn}/C_2] + r \quad if \quad 0 < (\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2) - [\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2] \le r \\ &= [\sum_{k=1}^{F}\sum_{j=1}^{J_K} q_{kjtn}/C_2] + 1 \quad if \quad r < \sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2 - [\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2] < 1 \end{aligned}\right\} for \quad all \quad n = 1, all \quad t \tag{2.3b}$$

$$q_{kjtn} \ge \sum_{v=1}^{\lambda} d_{kjt(v+u)}^{'} \quad for \quad all \quad n = 1,2,3,...,N; u = 0,\lambda,2\lambda,3\lambda,...,(N-1)\lambda \tag{2.4}$$

$$d_{kjtn} = \sum_{v=1}^{\lambda} d_{kjt(v+u)}^{'} \quad for \quad all \quad n = 1,2,3,...,N; u = 0,\lambda,2\lambda,3\lambda,...,(N-1)\lambda \tag{2.5}$$

$$r_{tn}^1 \ge 0 \quad for \quad all \quad t,n \tag{2.6a}$$

$$q_{kjtn} \ge 0, \quad I_{kjtv}^i \ge 0, \quad for \quad all \quad k,j,n,t,v \tag{2.6b}$$

$$I_{kjtn}^1 = I_{kjt,n-1}^1 + z_{kjtm} - q_{kjtn} \quad for \quad all \quad k,j,t,m \quad n = 1,1+\tau,1+2\tau,...1+(M-1)\tau \tag{2.7}$$

$$I_{kjtn}^1 = I_{kjt,n-1}^1 - q_{kjtn} \quad for \quad all \quad k,j,t,m \quad n = 2,3,4,..,\tau,\tau+2,\tau+3,...,2\tau,2\tau+2,...,N \tag{2.8}$$

Constraints (2.4) and (2.5) state the relationship between the transporting amount and the demand quantity. First, let a period t be subdivided into V smaller periods (e.g.

day). In the v[th] smaller period, R retailers' demand of product j of factory k is d'_{kjtv}. In the period t, we considered multiple deliveries of an order; the demand quantity of a shipment of product j of factory k is equal to $d_{kjtn} = \sum_{v=1}^{\lambda} d'_{kjt(v+u)}$. The total amount, $\sum_{k=1}^{F}\sum_{j=1}^{J_K} d_{kjtn}$, which includes F factories' J_k products, are transported to retailers from the DC. N is the number of shipments per order from the DC to retailers. One shipment has to cover the demand of λ smaller periods (i.e. $V = \lambda N$). That is, $q_{kjtn} \geq \sum_{v=1}^{\lambda} d'_{kjt(v+u)}$.

Constraints (2.1) and (2.2) are the inventory balance of retailers. The quantity, q_{kjtn}, of one batch of products that are transported to retailers from the DC, will meet the customer demands, d'_{kjtv}, of λ smaller periods. Constraints (2.3) define a container quantity problem in which we must deliver a quantity $\sum_{k=1}^{F}\sum_{j=1}^{J_K} q_{kjtn}$ to retailers from the DC for the n^{th} shipment in period t. When a partial truck load, $\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2 - [\sum_{k=1}^{F}\sum_{j=1}^{J_k} q_{kjtn}/C_2]$, is less than r (r<1) trucks, it will be charged with r trucks, and if the partial truck load is larger than r trucks, it will be charged with one truck. Constraints (2.7) and (2.8) are the inventory balance of the distribution center.

- **Typical Partially-Integrated Model**

  The logistics centre can be classified by several kinds of different type, for example, one of them is only charge the logistics expenses and having not trader flow (no buying and selling). The DC is an extra layer between suppliers and retailers and can be established by suppliers, or DC is integrated backward by retailers. On the other hand, the DC can play two different roles. One is to store inventory and the other is to serve as a transfer location. The retailers and the DC cooperate to determine the optimal transporting amount by minimizing the total relevant cost of both sides. In customer the highest setting and strong commercial competition, the manufacturers produce and transport according to the optimal quantity of the DC and the retailers. This model is called typical partially-integrated model.

  The procedure used to minimize the integrated distribution model (DS) is as follows.

$$\text{Min} \quad TOT_1 = \sum_{t=1}^{T}\sum_{k=1}^{F} H_{kt} + \sum_{t}^{T}\sum_{n}^{N} c^1 r_{tn}^1 \qquad \text{(DS)}$$

The number of shipments from manufacturer to the DC, the number of shipments from the DC to the retailers, producing quantity, x_{kjmt}, and delivering quantity, z_{kjtm}, are found by meeting the retailers' demand quantity (d_{kjtn}) and minimizing the total cost (TOT1). Then, the information is substituted into the total costs of a system (TOT), and the total cost can be obtained.

Production Scheduling

The production planning problem, which we denote by (PS), consists of the setup costs (Q_{kt}), the inventory holding cost (H'_{kt}) of the DC, and transportation cost, $\sum_{m=1}^{M} c^0 r^0_{kmt}$, from the manufacturers to the distribution center (Eksioglu et al., 2006). The objective function represents the cost functions, consists of finding values for $x_{kjtm}, z_{kjtm}, y_{kjtm}$ for all *k, j, m, t*. The formulation of (PS) can be written as

$$\text{Min} \quad TOT_2 = \sum_{t=1}^{T}\sum_{k=1}^{F}(Q_{kt} + H'_{kt} + \sum_{m=1}^{M} c^0 r^0_{kmt}) \tag{PS}$$

Where

$$Q_{kt} = \sum_{j=1}^{J_k} s_{kj} y_{kjmt}$$

$$H'_{kt} = \sum_{m=1}^{M}\sum_{j=1}^{J_k} h^1_{kj} I^0_{kjmt} + \sum_{n=1}^{N}\sum_{j=1}^{J_k} h^1_{kj} I^1_{kjnt}$$

Subject to

$$x_{kjtm} \le W y_{kjtm} \quad for \quad all \quad k, j, t, m \tag{2.9}$$

$$I^0_{kjtm} = I^0_{kjt,m-1} + x_{kjtm} - z_{kjtm} \quad for \quad all \quad k, j, t, m \tag{2.10}$$

$$r^0_{ktm} = [\sum_{j=1}^{J_k} z_{kjtm} / C_1] \quad for \quad all \quad m = M, M-1, \ldots, 2 \tag{2.11a}$$

$$
\left.\begin{aligned}
r^0_{ktm} &= [\sum_{j=1}^{J_k} z_{kjtm}/C_1] \quad if \quad \sum_j z_{kjtm}/C_1 = [\sum_j z_{kjtm}/C_1] \\
&= [\sum_{j=1}^{J_K} z_{kjtm}/C_1] + r \quad if \quad 0 < \sum z_{kjtm}/C_1 - [\sum_j z_{kjtm}/C_1] \le r \\
&= [\sum_{j=1}^{J_K} z_{kjtm}/C_1] + 1 \quad if \quad r < \sum z_{kjtm}/C_1 - [\sum_j z_{kjtm}/C_1] < 1
\end{aligned}\right\} for \quad m=1, \quad and \quad all \quad k,t \qquad (2.11b)
$$

$$
z_{kjtm} \ge \sum_{n=1}^{\tau} d_{kjt(n+u)} \quad for \quad all \quad m = 1,2,3,...,M; u = 0,\tau,2\tau,...,(M-1)\tau \qquad (2.12)
$$

$$
y_{kjtm} \in \{0, \ 1\}, \quad x_{kjtm} \ge 0, \quad z_{kjtm} \ge 0 \quad for \quad all \quad k, j, t, m \qquad (2.13a)
$$

$$
r^0_{ktm} \ge 0 \quad for \quad all \quad k,t,m \qquad (2.13b)
$$

$$
q_{kjtn} \ge 0, \quad for \quad all \quad k, j, n, t \qquad (2.6b)'
$$

Constraint (2.9) requires setups for each product for shipments in periods in which production of that product occurs. The parameter W is a sufficiently large positive number. Namely, it is no restriction on production capacity. Constraint (2.10) is the inventory balance concern production and transportation of the factory. Constraints (2.11) define a container quantity problem in which we must deliver a quantity $\sum_{j=1}^{J_k} z_{kjmt}$ to the distribution center from factory *k* for the m^{th} shipment in period t. When a partial truck load, $\sum_{j=1}^{J_k} z_{kjtm}/C_1 - [\sum_{j=1}^{J_k} z_{kjtm}/C_1]$, is less than *r* (*r*<1) trucks, it will be charged with *r* trucks, and if the partial truck load is larger than *r* trucks, it will be charged with one truck.

The number of direct trips from a factory to the DC, r^0_{kmt}, is calculated as the calculating rule for r^1_{tn}. The particular scenario we consider concerns factories that produce a number of products over time and the products are distributed by a fleet of trucks to the distribution center (DC) immediately. The inventory of finished good is maintained at the distribution center and delivered to the retailers.

Fully-Integrated Model

A lot of approaches have been taken to discuss different aspects of the integrated model (e.g. Chandra and Fisher, 1994; Eksioglu et al., 2006). If all parties, instead of determining their policies independently, decided to cooperate and adopt the integrated policy, then considerable savings could be achieved (Goyal, 1976).

The ideal goal is to reduce the total cost of system, but the expected benefits are not enjoyed by single party only. Because of the conflicting nature, there is usually no solution to optimize both objectives simultaneously. Masud & Hwang' (1980) proposed three multiple objective decision making (MODM) methods. One of them is Step Method (STEM).

The objectives functions are listed below:

$$\text{Min } (TOT_1 \quad , TOT_2) \tag{COS}$$

$$TOT_1 = \sum_{t=1}^{T}\sum_{k=1}^{F} H_{kt} + \sum_{t}^{T}\sum_{n}^{N} c^1 r_{tn}^1 \tag{DS}$$

$$TOT_2 = \sum_{t=1}^{T}\sum_{k=1}^{F} (Q_{kt} + H_{kt}^{'} + \sum_{m=1}^{M} c^0 r_{kmt}^0) \tag{PS}$$

Subject to (2.1)-(2.13)

The procedure used to coordinate production and distribution planning (COS) includes (DS) and (PS). The solutions of (COS) minimize TOT_1 and TOT_2 simultaneously. Because of its connection with the DS model, the quantity, z_{kjtm}, of one batch of products that are transported to the DC from manufacturers will be sent to retailers with τ shipments with a volume of q_{kjtn}. In addition, x_{kjmt}, z_{kjtm}, y_{kjtm}, M, and N are obtained using multiple objective decision method.

Objective function:

Max { f_1, f_2 }

Where $f_1 = -TOT_1$, $f_2 = -TOT_2$

A feasible solution to the Linear Programming problem is sought which is the nearest in the MINIMAX sense to the ideal solution:

$$\underset{\{x,\lambda\}}{Min}\lambda$$

s.t. $\lambda \geq \{ f_i^* - f_i(x)\} \cdot \pi_i \quad i = 1,2$

x$\in X^r$

where λ=Max$\{ f_i^* - f_i(x)\} \cdot \pi_i$, and $f_i^* = Max\{ f_i(x)\} \quad i = 1,2$

π_i gives the relative importance of the distance to the ideal solution

where $\pi_i = \dfrac{\alpha_i}{\alpha_1 + \alpha_2}$, $\alpha_i = \dfrac{f_i^* - f_i^0}{f_i^*}$, and $f_i^0 = Min\{ f_i(x)\} \quad i = 1,2$

If some objectives are satisfactory and others are not, then it's allowed to modify in the (r+1)th cycle. The feasible region is modified as

$$X^r + 1 = \begin{cases} X^r \\ f_1(x) \cdot \geq f_1(x^r) - \Delta f_1(x^r) \\ f_2(x) \geq f_2(x^r) \end{cases}$$

NUMERICAL EXPERIMENTS

The policy described in this paper is illustrated with 9 distinct test cases, which we solve using Visual basic 6.0 and Lingo 8.0, to demonstrate the validity of three echelon production/distribution coordination. The test cases were used to explore the impact of the number of retailers and products, as well as the setup unit cost and holding inventory unit cost, and focused on the factorial analysis of the number of retailers and products, the setup unit cost, and the holding inventory unit cost.

The examples in this paper had no restrictions on production capacity. For all cases, setup costs and holding costs do not vary by product, i.e., $s_{kj} = s$, $h_{kj}^1 = h^1$, and $h_{kj} = h^i$. Other information for all discussed cases: T=1, F=3, C_1=3500, C_2=500, c^0=14700, c^1=3000, $I_{kjt,0}^0$=0, $I_{kjt,0}^1$=0, $I_{kjt,0}^i$=0, and V=30.

The inventory cost is for the entire inventory in the system, whether at the distribution center or at the retailers. The total transportation cost which is determined by the procedures outlined in Section 2.1 is equal in period t for the same problem. Without influencing the comparisons of the total costs, the transportation costs have not shown in the data. In this section, the performance of fully-coordination and partial-coordination is compared. Routing problem is not considered in this paper, for its complication and being widely discussed in literature. A related review can be found in the paper presented by Chandra and Fisher (1994).

The goal of this study was the decision aspect: the procedure is to coordinate inventory and distribution planning in the first stage, and then, the manufacturers' production scheduling is integrated with the distribution scheduling problem. We focus on the implementation and linkage of the two integrated models in order to make operation really feasible.

Typical partial-integrated model is defined as quantity of products which manufacturers produced and transported according to the result that achieves the minimum total cost of the DC and the retailers. However, Partial-integrated model has not reached the minimum total cost of a system. Fully-integrated model can reach the minimum total cost of the both stages simultaneously. The savings can then be analyzed and compared to the two degree integration policies. The total relevant cost of the fully-integrated policy is significantly less than the total cost of the partial-integrated policy, with average percentage decreases from 0.38% to 21.59%.

Table 1 Detailed cost of fully-integrated and partial-integrated model

	Partial-integrated			Fully-integrated		
Prob. No.	Setup	Inv	Total	Setup	Inv	Total
1	43000	14808	57808	29000	21149	50149
2	86000	14808	100808	60000	22753	82753
3	129000	14808	143808	90000	22753	112753
4	43000	26061	69061	34000	34799	68799
5	86000	29451	115451	58000	41885	99885
6	129000	29451	158451	90000	45240	135240
7	54000	30149	84149	46000	35267	81267
8	86000	43915	129915	66000	53553	119553
9	129000	43915	172915	87000	62391	149391

Table 2 Coordination effect

Prob. No.	J	R	hr/hd	s	P-Total	F-Total	Cost decrease from coordination (%)
1	9	10	0.25/0.025	1,000	57,808	50,149	13.25
2	9	10	0.25/0.025	2,000	100,808	82,753	17.91
3	9	10	0.25/0.025	3,000	143,808	112,753	21.59
4	9	10	0.5/0.05	1,000	69,061	68,799	0.38
5	9	10	0.5/0.05	2,000	115,451	99,885	13.48
6	9	10	0.5/0.05	3,000	158,451	135,240	14.65
7	9	10	0.75/0.075	1,000	84,149	81,267	3.42
8	9	10	0.75/0.075	2,000	129,915	119,553	7.98
9	9	10	0.75/0.075	3,000	172,915	149,391	13.6

Table 1 and table2 reveals the detailed cost and coordination effect for test cases respectively. From these tables, there are many observations that can be made about how problem parameters impact the performance of fully-coordination. With other parameters constant, the higher setup costs are, the more influence on the saving percentage is. But, the lower the holding inventory unit cost is, the more apparent the effect is.

CONCLUSION

The authors extend the previous model (two-echelon coordination) to construct a three echelons supplier-buyer relationship that accommodates a distribution center as intermediary. Additionally, the strategy for two stages integration of the three echelons supplier-buyer relationship is proposed. We compare the total cost with fully integration and the total cost with partially integration. The typical case (partially integration), in which a buyer possesses dominance to force and adopt shipment sizes of the first stage integration, have been illustrated to compare with coordinated model.

Overall, this study reveals the following findings:

1. A fully-integration policy will result in tremendous savings in the total system cost for the supply chain.
2. The manufacturers are the main beneficiary, in which the total relevant cost can be reduced significantly. In order to have a better cooperation with the buyer, the manufacturers will pass part of his savings to the DC even if he perfectly dominates the buyer (Lu., L., 1995).
3. We offer proposition to the logistics industry. It will result in tremendous savings by linking of the two integrated models, no matter DC is set up by manufacturers or the

retailers. The benefited party can enforce the integrated policy by offering compensation for the loss incurred. This can be done with a premium paid to the retailer.

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