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QUANTIFICATION OF THE PERFORMANCE BENEFITS OF OUTSOURCING INVENTORY MANAGEMENT AND TRANSPORTATION ACTIVITIES TO LOGISTICS COMPANIES FOR COMPETITIVE ADVANTAGE

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ABSTRACT

This research studies the current operational practices in the Turkish automobile supplier industry and proposes a new operational scheme to lower the transportation costs while not increasing the production and inventory costs of the suppliers. In the proposed operational scheme suppliers outsource their inventory management and transportation activities to logistics companies. Furthermore, the suppliers share their demand information and inventory updating plans with the logistics company. The focus then is to quantify the performance benefits of the proposed operational scheme in terms of costs.

Keywords: Supply Chain Management, Distributed Decision Making, Logistics Outsourcing, Third Party Logistics, Make to Order Production

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1. INTRODUCTION

Automobile industry is dominated by large car manufacturers. As in other industries, the competition gets fiercer and therefore profit margins shrink continuously. In order to survive and protect their profit margins car manufacturers require their suppliers to become more cost effective which implies that suppliers must also try to apply state-of-the art operations management techniques. Therefore, minimizing the cost of non-value-added operations such as transportation and inventory holding at the supplier level is becoming of critical importance for suppliers.

This paper investigates current industry practice in inventory management and transportation in the Turkish supplier industry, and proposes an alternative operational scheme for inventory management and transportation making use of third party logistics. Both of the current and proposed practices are modeled and their performances evaluated.

2. LITERATURE SURVEY

Third Party Logistics have attracted attention in literature since demand of advance logistics services dictates third party logistics (TPL) development (Hertz and Alfredsson, 2003). Increased competition between firms and also new opportunities such as advancements in computers and communication technology necessitates specialized logistic service (Sheffi, 1990). The level of expertise of logistics service pushes companies outsource their logistics activities to a third party highly specialized logistic provider instead of making high investment on it and they focus only to their core businesses.

Different strategies have been developed for improving the efficiency in TPL. For example, Tyan, Wang and Du (2003) introduce new shipper-carrier partnership strategy-collaborative transportation management (CTM)- in which carrier (TPL provider) is a strategic partner for information sharing and partnership in supply chain. Authors continue that CTM promises to reduce transit times and contribute asset utilization. TPL promises numerous advantages. Analysis results related to 124 firms in Malaysia point out that outsourcing logistics activities may lower logistics costs, and increase logistics system performance and customer satisfaction (Sohail and Sohal, 2003).

Berglund et al’s (1999) study on strategies of TPL providers sheds light on the source of value adding by TPL providers; (1) “Operational efficiency”- as TPL providers doing their core business they are able to offer better performance/cost ratio especially in warehouse management with information technology skills, (2) “Sharing Resources” let them benefit from economies of scale and reduce logistics cost, (3) “Improving Supply Chain” such as cross-docking facilities may eliminate unnecessary storage of inventories.

Furthermore, Hertz and Alfredsson (2003) conclude that in automotive and computer industry TPL usage meets the demand for quick deliveries of huge amount of spare parts. This study examines the potential value added by TPL in automotive industry by using optimization as a modeling methodology which is one of the modeling approaches to the logistic problems in the literature. Powers’ (1989) analysis on modeling methods such as optimization, heuristic and simulation illustrates that optimization is best whenever it fits, and other methods such as heuristic and simulation is used whenever optimization is not possible due to complexity and run-time of problem.

Today's competitive business environment has led organizations to consider trust and cooperation in some network on the way to effective competition. This brought collaborative association with suppliers, where gaining mutual benefits for the parties involved, is the main target (Carr and Pearson, 1999; Doney and Cannon, 1997; Rubin and Carter, 1990, Janda et al., 2002). Advocates of collaborative relationships state that firms can attain better lead times and quality, increase in operating flexibility, long-term cost reductions by sharing strategic information with suppliers (Bertrand, 1986).

The model (Janda et al., 2002) which searches for the performance outcomes of the buyer engaging in a relational orientation toward its supplier shows that long-term relationships with suppliers cause buyers to ensure superior lead times, quality, increased operating flexibility, and ongoing cost reductions.

The study of Schneeweiss and Zimmer (2004) has another perspective for supply chain management. They focus on the coordination of in-house assembly and out-house manufacturing which indicates problems of distributed decision making and those having private information. The study, in which they use a centralized model to evaluate non-centralized (team-oriented) coordination mechanisms, combines both coordination-oriented and logistics–oriented direction. In their study they assume that both parties maintain some privacy (i.e. they do not reveal all their data, which consequently results in an asymmetric information state) since their main concern is to quantify the effect of private information on the overall performance of the supply link. The study employs the theory of hierarchical planning and identifies producer as the top-level and the supplier as the base-level. They found out that in a situation in which parties seem to cooperate, the reactive anticipation seems to be the reasonable coordination scheme, and in this situation the capacity situation of the supplier and the costs of a capacity adaptation is the only data that is significant and should be carefully exchanged.

3. PROBLEM STATEMENT

3.1 Description of the Current Situation

The automobile industry is dominated by large car manufacturers worldwide. On the other hand, the supplier companies are relatively small in size. The operational relationship between the manufacturers and suppliers are mainly coordinated by the manufacturers, i.e. manufacturers specify the time and place of the delivery as well as the amount of parts suppliers are supposed to deliver. Suppliers usually disregard inventory management due the nature of the relationship with the manufacturers and not usually having the state-of-the art know-how on inventory management. Basically, each supplier tries to minimize the production costs, given the order specification of manufacturers, while guaranteeing the existence of a feasible transportation schedule; and then tries to minimize the transportation costs disregarding inventory costs, given the schedule of minimum cost production. Suppliers also try to produce as late as possible while minimizing cost of production which can be regarded as a heuristic way of including inventory costs in the objective.

This decision scheme is illustrated in Figure1. The car manufacturers are called assemblers in figures and models from now on. Suppliers, in general, do not own the

transportation media that are used for delivering parts to manufacturers. Instead, there are transportation firms that lease transportation vehicles to suppliers.
The delivery scenario of the whole supplier manufacturer system is illustrated in Figure2. Note that this figure does not necessarily demonstrate the respective locations of transporter, suppliers and assemblers; instead, this figure just demonstrates the flow direction of the transportation vehicles.

Based on this description, the operation of the current system can be summarized as follows. The manufacturers pass orders and associated specifications to suppliers. Each supplier determines their production and transportation schedule as illustrated in Figure1. While carrying out the transportation, each supplier leases transportation vehicles from transporters.

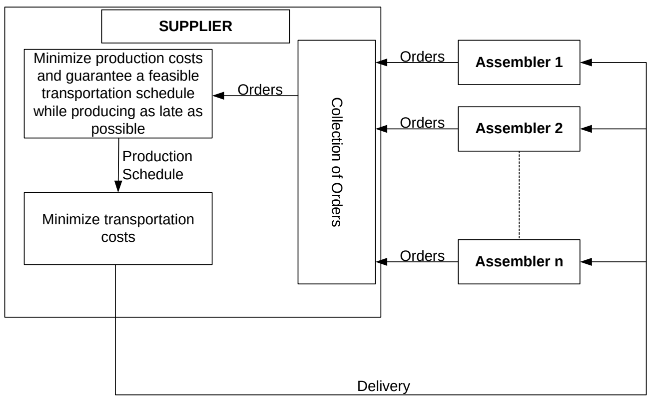

Figure 1. Current Supplier Decision Mechanism

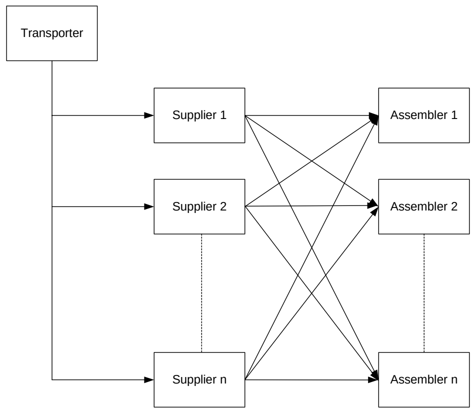

Figure 2. Delivery Scenario of Supplier Manufacturer System

3.2 Description of the Proposed Operational Scheme

We propose that the transportation scheduling as well as the previously overlooked or incompetently done inventory management tasks of the suppliers are outsourced to a logistics company. In this case, the suppliers identify the production cost minimizing schedule and then pass the schedule information to the logistics company with the demand information of the manufacturers. Then, the logistics companies carry-out the inventory management and transportation activities optimally. There is a regulating control input for each type of product to the supplier's objective function which motivates the supplier to produce as late as possible to help minimize the inventory costs of the respective products.

Basically, the inclusion of the control input in the supplier's objective function implies that the inventory costs are virtually shared between the logistics company and the supplier, which prevents the opportunistic behavior of supplier side on the inventory costs.

This decision mechanism is illustrated in Figure3. For this decision mechanism, a sample delivery scenario is illustrated in Figure4. All of the parts from suppliers are collected and cross-docked at a cross-docking center. After cross-docking, the parts are delivered to the manufacturers according to their order specifications.

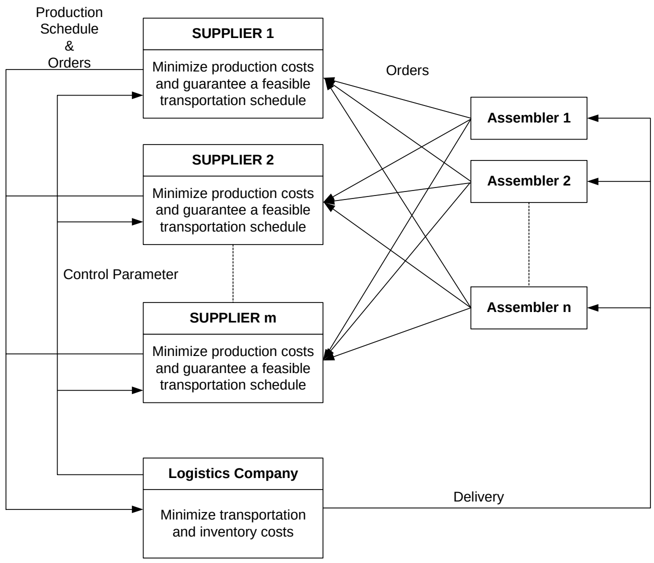

Figure 3. Proposed Decision Mechanism

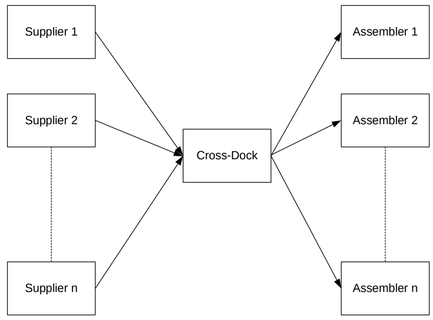

Figure 4. Sample Delivery Scenario for Proposed Decision Mechanism

3.3 General Modeling Framework

The production system of the suppliers is composed of different production modes representing the different setups of the system. In each mode, the suppliers are capable of producing different products. The maximum rate of production for each product is limited. Changing from one node to another requires a cleanup time for the former mode and a setup time for the latter mode. Length of each mode depends on supplier’s decision, i.e. the length of each mode may vary. A setup cost is incurred when the supplier starts a new production mode. Furthermore, there is a fixed cost paid for each period the supplier is in a specific production mode. A variable cost is paid for each unit of product produced. The suppliers are assumed to have sufficient storage capacity for any production-transportation plan.

Similar to the production system, the transportation vehicles may have different transportation modes and in each mode their transportation capabilities may be different. That is, the ability to carry a product may be present in some modes whereas it may be absent at others. One easy way to visualize this is to think of truck carrying petroleum in one mode and carrying bricks in another. The speed of transportation may change for each vehicle and each associated transportation mode. When a transportation activity is to start from a supplier a fixed cost is incurred. Each vehicle type in a specific mode has a variable cost of operating per period. The number of vehicles of each type is assumed to be high enough so that vehicle shortage is not a problem.

The planning is done for a given finite length of horizon. The assemblers specify their demand of each product from each supplier at the beginning of the planning horizon. The demand values do not change during the planning horizon. Naturally, the demand of assemblers is specified in make-to-order fashion with the property that the delivery time must be exact.

Based on this framework, the indices and sets that are utilized while developing the necessary optimization formulations are declared as follows.

K	:	length of planning horizon	θ	:	index of operating modes
k	:	index for planning horizon, 1..K	J	:	set of products
S	:	set of suppliers	j	:	product index, $j \in J$
s	:	supplier index, $s \in S$	V	:	set of vehicle types
A	:	set of assemblers	v	:	vehicle type index, $v \in V$
a	:	assembler index, $a \in A$	M	:	set of vehicle modes
Θ_s	:	set of operating modes for s	m	:	vehicle mode index, $m \in M$

The parameters are declared as follows.

$IA_j^s 0$	:	initial inventory of product j at s	fm_θ^s	:	fixed cost of being in θ at s
$R_{\theta,j}^s$	:	max rate of production for j in θ at s	$vp_j^{s,\theta}$	:	variable cost of production of j at s in θ
ST_θ^s	:	setup time of θ at s	sc_θ^s	:	setup cost of θ at s
CT_θ^s	:	cleanup time of θ at s	ft	:	fixed cost of transportation
$LT_{v,m}^{\alpha,\beta}$	:	lead time from α to β by v in m	ic_j^s	:	inventory cost of j at s
tm_a^s	:	min time of transportation from s to a	vt_m^v	:	variable transportation cost of v in m
d	:	time index at which demand for next period begins	$LP_j^s(k)$	:	late produce parameter at s for j at k
$f_j^{v,m}$	:	fraction of volume of v in m occupied by one unit of j	$CI_j^s(k)$	:	control input applied to s for j at k by logistics company

$$d_j^{a,s}(k)=\begin{cases}0, k \le d \\ \text{demand of } a \text{ of } j \text{ from } s \text{ to be delivered at } k, k \ge d\end{cases}$$

d is the advance time of notification of demand. That is, the assemblers notify suppliers of their demand at least $d-1$ periods before so that at time d the first positive value of demand can be observed. For example, if d is 3 and K is 5, then demand can be 0, 0, 10, 10, 10; or 0, 0, 0, 10, 0 but demand cannot have any non-zero value in the first two periods.

Among these parameters $LP_j^s(k)$ and $CI_j^s(k)$ needs more explanation. $LP_j^s(k)$ is the parameter defined to incorporate the suppliers' behavior to produce as late as possible of a given product to heuristically incorporate their inventory costs in the objective function. If $LP_j^s(k)$ is defined as a decreasing parameter for increasing k and included in the objective function of the supplier for each unit of product produced in each period, then the heuristic treatment of suppliers to inventory costs can be included in the optimization formulation. On the other hand, $CI_j^s(k)$ is the control input applied by the logistics company to the suppliers.

Likewise, if $CI_j^s(k)$ is defined by the logistics company as a decreasing parameter for increasing k and imposed as a cost to suppliers for each unit of product that they place in the inventory, then the suppliers will produce as late as possible which will help the logistics company to minimize their inventory costs. As elaborated before, control input facilitates the sharing of inventory costs between the suppliers and the logistics company and therefore helps to prevent opportunistic behaviors on the suppliers' side.

3.4 Production Model

The variables that are used in the optimization of production are declared in the following list.

$IA_j^s(k)$	:	accumulated inventory of *j* at *s*	$B_{\theta,j}^s(k)$	:	amount produced of *j* in θ at k at *s*
$p_\theta^s(k)$	:	$\begin{cases}1, \text{ if } s \text{ is in mode } \theta \text{ at } k \\ 0, \text{ otherwise}\end{cases}$	$zs_\theta^s(k)$	:	$\begin{cases}1, \text{ if } X1_\theta^s(k) \text{ is positive} \\ 0, \text{ otherwise}\end{cases}$
$f_\theta^s(k)$	:	$\begin{cases}1, \text{ if } \theta \text{ at } s \text{ is started at } k \\ 0, \text{ otherwise}\end{cases}$	$zc_\theta^s(k)$	:	$\begin{cases}1, \text{ if } Y1_\theta^s(k) \text{ is positive} \\ 0, \text{ otherwise}\end{cases}$
$X1_\theta^s(k)$, $X2_\theta^s(k)$	:	setup time control variables	$Y1_\theta^s(k)$, $Y2_\theta^s(k)$	:	cleanup time control variables

The model for the suppliers' production for the current scenario is provided in Eq.(1). The model for suppliers' production for the proposed scenario is the same as presented in Eq.(1) except the objective function. The objective function of the suppliers for the proposed scenario is presented in Eq.(2).

$$\begin{aligned} \textit{Minimize } z = & \sum_{\theta\in\Theta_s}\sum_k sc_\theta^s * f_\theta^s(k) + \sum_{\theta\in\Theta_s}\sum_k fm_\theta^s * p_\theta^s(k) + \sum_{\theta\in\Theta_s}\sum_j\sum_k vp_j^{s,\theta} * B_{\theta,j}^s(k) \\ & + \sum_{\theta\in\Theta_s}\sum_j\sum_k LP_j^s(k) * B_{\theta,j}^s(k) \end{aligned} \tag{1}$$

subject to

$$\sum_{\theta\in\Theta_s} p_\theta^s(k) \le 1 \; \forall k$$

$$f_\theta^s(1) \ge p_\theta^s(1) \; \forall \theta \in \Theta_s$$

$$f_\theta^s(k) \ge p_\theta^s(k) - p_\theta^s(k-1) \; \forall k \ge 2, \theta \in \Theta_s$$

$$B_{\theta,j}^s(k) \le X1_\theta^s(k) * R_{\theta,j}^s \; \forall k, \theta \in \Theta_s, j$$

$$B_{\theta,j}^s(k) \le Y1_\theta^s(k) * R_{\theta,j}^s \; \forall k, \theta \in \Theta_s, j$$

$$\sum_j B_{\theta,j}^s(k) / R_{\theta,j}^s \le 1 \; \forall k, \theta \in \Theta_s$$

$$\sum_{t=\max\{1,k-ST_\theta^s\}}^{k} p_\theta^s(t) - ST_\theta^s = X1_\theta^s(k) - X2_\theta^s(k) \; \forall k, \theta \in \Theta_s$$

$$X1_\theta^s(k) \le zs_\theta^s(k) \; \forall k, \theta \in \Theta_s$$

$$X2_\theta^s(k) \le \left(1 - zs_\theta^s(k)\right) * ST_\theta^s \; \forall k, \theta \in \Theta_s$$

$$\sum_{t=k}^{\min\{K,k+CT_\theta^s\}} p_\theta^s(t) - CT_\theta^s = Y1_\theta^s(k) - Y2_\theta^s(k) \; \forall k, \theta \in \Theta_s$$

$$Y1_\theta^s(k) \le zc_\theta^s(k) \; \forall k, \theta \in \Theta_s$$

$$Y2_\theta^s(k) \le \left(1 - zc_\theta^s(k)\right) * CT_\theta^s \; \forall k, \theta \in \Theta_s$$

$$IA_j^s(k) \ge \sum_{t=d}^{k}\sum_a d_j^{a,s}\left(t + tm_a^s\right) \; \forall k \ge d$$

$$IA_j^s(k+1) = IA_j^s(k) + B_{\theta,j}^s(k) \; \forall k \le K-1$$

$$IA_j^s(1) = IA_j^s 0$$

All variables are greater than or equal to zero

$$\begin{aligned} z = & \sum_{\theta\in\Theta_s}\sum_k sc_\theta^s * f_\theta^s(k) + \sum_{\theta\in\Theta_s}\sum_k fm_\theta^s * p_\theta^s(k) \\ & + \sum_{\theta\in\Theta_s}\sum_j\sum_k vp_j^{s,\theta} * B_{\theta,j}^s(k) + \sum_j\sum_k\sum_{\theta\in\Theta_s} CI_j^s(k) * B_{\theta,j}^s(k) \end{aligned} \tag{2}$$

3.5 Transportation Model of the Current Scenario

The variables that are specifically used in the optimization of transportation are declared in the following list. α and β are generic indices.

$y_j^{\alpha,\beta,v,m}(k)$	:	Amount of j sent from α to β by v in mode m at k	$vs_{v,m}^{\alpha,\beta}(k)$	:	$\begin{cases} 0, & \text{if } VS_{v,m}^{\alpha,\beta}(k) = 0 \\ 1, & \text{otherwise} \end{cases}$
$VS_{v,m}^{\alpha,\beta}(k)$	:	Number of vehicles v sent from α to β in mode m at k			

For this case, we assume that the delivery procedure is exactly as described in Fig.2. That is, the vehicles sent from suppliers to manufacturers do not go from one assembler to another to make deliveries. Therefore, vehicle routing is not considered in the mathematical model. The model for the suppliers' transportation is provided in Eq.(3).

$$\begin{aligned}
&\textit{Minimize} \sum_a \sum_v \sum_m \sum_k ft * vs_{v,m}^{s,a}(k) + \sum_a \sum_v \sum_m \sum_k vt_m^v * LT_{v,m}^{s,a} * VS_{v,m}^{s,a}(k) \\
&\textit{subject to} \\
&\sum_v \sum_m y_j^{s,a,v,m}\left(k - LT_{v,m}^{s,a}\right) = d_j^{a,s}(k) \ \forall a, j, k \geq d \qquad \sum_j f_j^{v,m} * y_j^{s,a,v,m}(k) \leq VS_{v,m}^{s,a}\left(k - LT_{v,m}^{T,s}\right) \ \forall a,v,m,k \geq LT_{v,m}^{T,s} + 1 \\
&y_j^{s,a,v,m}(k) = 0 \ \forall a,v,m,j,k \leq d - LT_{v,m}^{s,a} - 1 \qquad VS_{v,m}^{s,a}(k) \leq M * vs_{v,m}^{s,a}(k) \ \forall a,v,m,k \\
&y_j^{s,a,v,m}(k) = 0 \ \forall a,v,m,j,k \leq K - LT_{v,m}^{s,a} + 1 \qquad IA_j^s(k) \geq \sum_a \sum_v \sum_m \sum_{t=1}^{k} y_j^{s,a,v,m}(k) \ \forall j,k
\end{aligned} \tag{3}$$

All variables are greater than or equal to zero

where, T stands for the transportation company so that $LT_{v,m}^{T,s}$ is the time to go from the transportation company T to supplier s by vehicle type v in mode m.

3.6 Transportation and Inventory Model of the Proposed Scenario

For this case, we assume that the delivery procedure is exactly as described in Figure4. That is, there is a single logistics firm, which has a cross-docking site. The transportation vehicles are located at the cross-docking site and after loading parts from the suppliers, they possibly cross-dock their loads to other vehicles which deliver the parts to the manufacturers' site. Routing of vehicles is excluded in the model for the sake of simplicity similar to the previous section. Variables specific to this scenario of transportation are defined as follows.

$I_j^s(k)$: inventory of product j at s at time k

$yl_j^{s,L,v,m}(k)$: amount of j sent from s to cross-dock in v in m

$ya_j^{s,a,v,m}(k)$: amount of j sent from cross-dock to a in v in m by s

The transportation and inventory model for this scenario is illustrated in Eq.(4).

$$
\begin{aligned}
&\textit{Minimize} \sum_{s}\sum_{j}\sum_{k} ic_j^s * I_j^s\left(k\right) + \sum_{n\in A\cup S}\sum_{v}\sum_{m}\sum_{k} ft * vs_{v,m}^{L,n}\left(k\right) \\
&\qquad + \sum_{s}\sum_{v}\sum_{m}\sum_{k} vt_m^v * LT_{v,m}^{s,L} * VS_{v,m}^{L,s}\left(k\right) + \sum_{a}\sum_{v}\sum_{m}\sum_{k} vt_m^v * LT_{v,m}^{L,a} * VS_{v,m}^{L,a}\left(k\right)
\end{aligned}
$$

subject to (4)

$$IA_j^s\left(k\right) = \sum_{v}\sum_{m}\sum_{t=1}^{k} yl_j^{s,L,v,m}\left(t\right) + I_j^s\left(k+1\right)\ \forall s,j,k \le K-1$$

$$I_j^s\left(1\right) = IA_j^s\left(1\right)\ \forall s,j$$

$$IA_j^s\left(K\right) \ge \sum_{v}\sum_{m}\sum_{t=1}^{K} yl_j^{s,L,v,m}\left(t\right)\ \forall s,j$$

$$\sum_{j} f_j^{v,m} * yl_j^{s,L,v,m}\left(k\right) \le VS_{v,m}^{L,s}\left(k - LT_{v,m}^{L,s}\right)\ \forall s,v,m,k \ge LT_{v,m}^{L,s} + 1$$

$$\sum_{v}\sum_{m} yl_j^{s,L,v,m}\left(k - LT_{v,m}^{s,L}\right) = \sum_{a}\sum_{v}\sum_{m} ya_j^{s,a,v,m}\left(k\right)\ \forall s,j,k \ge LT_{v,m}^{s,L} +$$

$$yl_j^{s,L,v,m}\left(k\right) = 0\ \forall s,v,m,j,k \le \max\left\{LT_{v,m}^{s,L}, LT_{v,m}^{L,s}\right\}$$

$$yl_j^{s,L,v,m}\left(k\right) = 0\ \forall s,v,m,j,k \ge K - LT_{v,m}^{s,L} + 1$$

$$ya_j^{s,a,v,m}\left(k\right) = 0\ \forall s,a,v,m,j,k \le d - LT_{v,m}^{L,a} - 1$$

$$ya_j^{s,a,v,m}\left(k\right) = 0\ \forall s,a,v,m,j,k \ge K - LT_{v,m}^{L,a} + 1$$

$$\sum_{s}\sum_{j} f_j^{v,m} * ya_j^{s,a,v,m}\left(k\right) \le VS_{v,m}^{L,a}\left(k\right)\ \forall a,v,m,k$$

$$VS_{v,m}^{L,s}\left(k\right) \le M * vs_{v,m}^{L,s}\left(k\right)\ \forall s,v,m,k$$

$$VS_{v,m}^{L,a}\left(k\right) \le M * vs_{v,m}^{L,a}\left(k\right)\ \forall a,v,m,k$$

$$d_j^{a,s}\left(k\right) = \sum_{v}\sum_{m} ya_j^{s,a,v,m}\left(k - LT_{v,m}^{L,a}\right)\ \forall a,s,j,k \ge d$$

All variables are greater than or equal to zero

where, L stands for the logistics company so that $LT_{v,m}^{L,s}$ is the time to go from the cross-docking site to supplier s by vehicle type v in mode m . $LT_{v,m}^{L,s}$ and $LT_{v,m}^{L,a}$ are similar.

3.7 Model of the Current Scenario

Each supplier first solves Eq.(1) and then solves Eq.(3) by specifying the $IA_j^s\left(k\right)$ values as illustrated in Fig.1. It is worth noting that $IA_j^s\left(k\right)$ is a variable for Eq.(1) whereas it is a parameter for Eq.(3). The total cost of operations for each supplier including the inventory costs are calculated by using the results of these two optimizations.

3.8 Model of the Proposed Scenario

Each supplier solves Eq.(1) with objective function specified as in Eq.(2) and passes the values of $IA_j^s\left(k\right)$ and $d_j^{a,s}\left(k\right)$ values to the logistics company, then logistics company solves Eq.(4) just as illustrated in Fig.3.

4. NUMERICAL ANALYSIS

In order to test the performance of the proposed operational scheme with respect to that of the existing operational scheme, a numerical example is constructed. All of the suppliers are assumed to be identical in their production capabilities, costs and the demand faced. The demand start parameter, d , is taken to be 11. The value of the demand of each assembler for each product that a supplier produces is taken to be 10 from the demand start time to the end of planning horizon. The production rate parameters are illustrated in Table 1.

Table 1. Production rate parameter, $R_{\theta,j}^s$, values

	θ	
j	1	2
1	200	0
2	0	200

The rest of the parameters necessary for defining the production model is are shown in Table 2.

Table 2. Parameter Values for Production Model

Parameter	$IA_j^s 0$	ST_θ^s	CT_θ^s	fm_θ^s	$vp_j^{s,\theta}$	sc_θ^s	$LP_j^s(k)$	$CI_j^s(k)$
Value	0	1	1	20	1	100	$vp_j^{s,\theta} * (K-k)$	$vp_j^{s,\theta} * (K-k)$

There are two types of vehicles. One is low capacity and the other is high capacity. Each type of vehicle has a single mode. Their transportation speeds are identical. The lead time parameters are illustrated in Table 3.

Each product in this system has identical volumes and shapes. Vehicle type 1 can carry a total of 10 units of products whereas vehicle type 2 can carry a total of 20 units of products. The fixed and variable costs for each vehicle type are shown in Table 4.

Table 3. Lead time parameter values

	L or T	s	a
L or T	-	2	2
s	2	-	4
a	2	4	-

Table 4. Fixed and variable costs for vehicles

Vehicle Type	ft_m^v	vt_m^v
1	10	2.5
2	15	3.75

The inventory cost is 4 for each product at each supplier.

Both current operational scheme's and proposed operational scheme's performance in terms of production, inventory and transportation costs are evaluated for K=15 and K=20. The benefits of the system did not change in terms of percentage for K=15 and K=20. The proposed system offered no operational cost benefit in terms of production and inventory costs. This is to be expected since $LP_j^s(k)$ and $CI_j^s(k)$ parameters are declared to be the same and the suppliers produce as late as possible with minimum cost. On the other hand, the transportation costs are significantly reduced in the proposed operational scheme. For one supplier and one assembler, i.e. the non-existence of collaboration, there is no change in the transportation cost. Beginning from two suppliers and two assemblers to six suppliers and six assemblers the percentage reduction in the transportation costs for each supplier with respect to number of suppliers and assemblers is plotted in Fig.5.

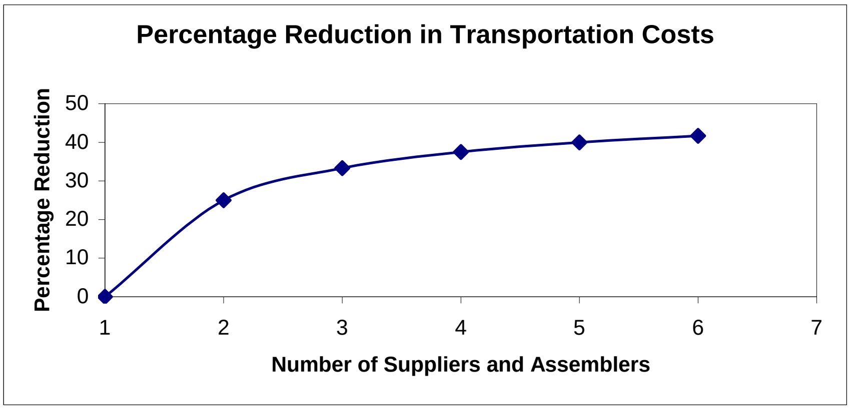

Figure 5. Percentage reduction in transportation costs with respect to number of assemblers and suppliers

The reduction in transportation costs was expected because using a cross-dock and outsourcing the inventory management and transportation enable the logistics firm to reduce the traffic which in turn reduces the fixed and variable costs of transportation.

5. CONCLUSIONS AND FUTURE RESEARCH

This study shows that it is possible to reduce the transportation costs as the number of suppliers and assemblers increase and when suppliers collaborate and outsource their inventory management and transportation activities to a logistics firm. Even when there are only two suppliers collaborating and there are two assemblers they serve the reduction in the transportation costs are 25%.

The current model can be improved by including routing constraints and the performance of both systems can be analyzed. Facility location problems for a logistics company can be analyzed in this setting. The model predictive control implementation of this study can be conducted to simulate the performance of the system in a relatively uncertain environment.

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