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THE EVALUATION OF COORDINATION POLICIES IN LOGISTICS SERVICES MARKETS

Vito Albino, Rosa Maria Dangelico, Antonio Messeni Petruzzelli[1]

DIMeG, Politecnico di Bari, Viale Japigia 182, 70126 Bari, ITALY

Nowadays, due to the increasing complexity and expansion of supply chains, logistics is becoming a more strategic activity for firms in terms of both time and cost performance. In this paper, the coordination in a logistics services market based on vehicle consolidation policy is considered. In particular, three coordination policies characterized by different levels of collaboration among the actors of a supply stage are identified. Then, a model is developed for evaluating the transportation, coordination, and service lateness costs affecting each coordination policy. Finally, different coordination policies and collaborative relationships among the actors operating in the supply stage of an Italian brickworks company are discussed as a case study.

1 INTRODUCTION

In the current economic scenario, few products for sale in any country are entirely produced by domestic firms making use of domestic inputs only. Then, in order to be customers responsive and costs effective, logistics is becoming more important for firms. Due to the high degree of specialization characterizing nowadays logistics, such activities are generally outsourced to specific actors who make these services their own core-business.

These actors, known as third-party logistics (3PL) providers or logistic service providers (LSPs) (Hertz and Alfredsson, 2003), permit the interconnectedness among the different actors of the supply chain, world-wide located.

In the literature, different types of logistics services carried out by 3PL providers have been identified (see for instance Lai and Cheng, 2004). Among the different types of logistics services, transportation is one of the most important for supply chains efficiency and effectiveness, as empirical researches conducted by scholars and practitioners demonstrated (e.g. Dapiran et al., 1996; Lieb and Bentz, 2004). The importance of transportation for the actual competitive scenario is also highlighted by the effort spent to design and manage effective and efficient transportation networks, such as point-to-point, corridor, and hub-and-spoke systems (Lapierre et al., 2004; Hesse and Rodrigue, 2006). An effective design of transportation systems involves also problems related to vehicle scheduling, vehicle routing, and lateral transhipments (see for instance Laporte et al., 1988; Dror and Langevin, 1997).

Great attention has been paid in literature to the important role played by coordination as a mechanism by which improving supply chain performance (Colombo and Mariotti, 1998; Xu and Beamon, 2006). A coordination mechanism consists of the informational structure, defining who obtains what information and

[1] Corresponding author: a.messeni.petruzzelli@poliba.it

how uses that information, and of the decision-making process, which helps to select the appropriate action from a set of alternative solutions (Marschak and Radner, 1972). An important matter concerning coordination regards the trade-off between centralized coordination structures and decentralized ones (Malone, 1987). Centralized structures consist of mechanisms based on a single decision maker acting in the interest of the whole system. On the contrary, in decentralized structures each actor selects the most appropriate actions for his own interest. Typical examples of these two coordination structures are represented by hierarchy, where a single actor coordinates the whole network, and market, where the coordination is assigned to market-transactions.

The role of centralized coordination structures seems to be brought into question. In particular, Malone (2004) discusses the opportunity to introduce coordination mechanisms based on market-transactions inside an organisation. In fact, the author introduces the notion of internal markets, used to move information quickly and efficiently in organisations characterised by great units interdependence and operating in dynamic and complex contexts.

Logistics represents a typical activity whose coordination is particularly important for the competitive advantage of supply chains and networks, especially when actors are vertically disaggregated and located in different places. A way in which logistics flows coordination can be achieved is by means of consolidation strategies (Albino et al., 2006), which are the processes of combining different items, produced and used at different locations (spatial consolidation) and/or at different times (temporal consolidation), into single vehicle load (Hall, 1987). Two types of spatial consolidation, namely vehicle and terminal, and one type of temporal one, namely inventory consolidation can be identified.

The aim of the paper is to analyse the role of coordination policies in order to create an organized logistics services market. In particular, vehicle consolidation of products is considered in the transportation service market for a supply stage. To cope with this aim, a model for evaluating the benefits (in terms of reduction of transportation costs) and the costs (in terms of increasing of coordination and service lateness costs) arising from consolidation, in different collaborative contexts, is developed.

The paper is structured as follows. In the next section a brief analysis of the consolidation strategies is provided. In section three the notion of organized logistics services markets is presented and the model is developed. Finally, a case study, based on the supply stage of a brickworks company, is presented and the main findings and results are discussed.

2 CONSOLIDATION STRATEGIES

Consolidation strategies can be analysed taking into account two different dimensions: quantity and time (Newbourne and Barrett, 1972).

Consolidation strategies depend also on the transportation models adopted, as shown by Hall (1995) who examines the interdependence between freight mode and shipment size when they are chosen simultaneously to minimize transportation and inventory costs.

Conway and Gorman (2006) study the benefits arising from a consolidation point (mixing centre). The authors, by means of a simulation of the distribution system of an automobile manufacturer, show that consolidation determines relevant benefits for the whole system, in terms of reduction of inventory holding time, increasing load factors, and reduction of variability of transportation means. However, some drawbacks rise, in particular for customer service. Then, trade-offs have to be considered between system logistics performance and customer service level.

Blanc et al. (2006) study transportation coordination analysing factory gate pricing (FGP) as a means by which achieving orders consolidation. Under FGP, products are collected by the retailer at the factory gates of the suppliers. Then, transportation of logistics flows is completely managed by retailers, because they orchestrate both primary distribution (from supplier to retailer distribution centres) and secondary one (from retailer distribution centre to the shops). Another consolidation strategy strictly related to the concept of FGP is vendor managed inventory (VMI, see for example Cetinkaya and Lee, 2000). Also VMI allows the control of inventory and primary distribution, and sometimes even secondary transportation, to a player in the supply chain. The difference compared with FGP is that in VMI the supplier and not the retailer is in charge of coordination.

3 COORDINATION POLICIES EVALUATION

We define an organized logistics service market as a hybrid organizational system ranging between market and hierarchy where logistics needs are satisfied through the collaboration and the coordination of the different actors involved in the system.

In a supply chain stage, referring to transportation services, three distinct actors are identified: i) suppliers, which have to deliver products to one or more customers; ii) customers, which require products from one or more suppliers; iii) 3PL, which provides the transportation service and coordinates logistics flows between suppliers and customers. Consolidation is then considered as coordination policy.

Two types of vehicle consolidation are distinguished, namely internal consolidation and external consolidation, with only one type of vehicle. Internal consolidation occurs when the 3PL consolidates the products that have to be delivered from one supplier to two or more of its customers. Instead, external consolidation occurs when a 3PL consolidates the products that have to be delivered from two or more suppliers to their customers.

In order to coordinate logistics services market different policies based on collaboration among actors are considered, namely total collaboration, supply-centered collaboration, and no collaboration. In the first policy total collaboration among customers and suppliers occurs and direct trips, internal consolidation, and external consolidation are adopted by 3PL. In particular, direct trips occur only when the total amount of products to be delivered from one supplier to one customer is equal to or greater than the vehicle load capacity. Internal consolidation is eventually adopted to convey the remaining products that have to be delivered from each supplier to its customers. Successively, if some products from more than two suppliers have to be still delivered, external consolidation can be adopted. In the second policy collaboration among one supplier's customers occur and direct trips and internal consolidation are adopted by 3PL, as in the total collaboration policy. However, in this case, if some products have to be still delivered, direct trips instead of external consolidation are adopted. In the third coordination policy, no collaboration among suppliers or customers occurs and logistics flows are managed by 3PL only through direct trips.

To compare these coordination policies a model, based on the Supply Chain Operations Reference[2] (SCOR) model, is developed to evaluate possible solutions in terms of benefits and costs. The benefits are mainly related to the reduction of transportation cost sustained by the 3PL, which depends on the route length of the vehicles. However, to achieve this cost reduction, the 3PL has to face costs, such as a the coordination cost and the service lateness cost. Then, to explore solutions and determine a negotiation between the actors, trade-offs between benefits and costs are needed. Coordination cost is evaluated as the 3PL's effort necessary to work out the service requirements coming from all the actors in order to obtain a specific solution, represented by the route selected to satisfy all the actors service requirements. Then, the coordination cost is strictly related to the number of service requirements, which on turn depends on the number of actors involved in the coordination policies. In fact, a one-to-one relationship between the actors and the service requirements is assumed. Service lateness cost can be related to the delay that can occur for delivering products to a customer adopting supply-centered or total collaboration respect to no collaboration policy.

In the following a heuristic algorithm is developed for a supply chain stage in order to determine the transportation cost sustained by the 3PL in each coordination policy. Then, the coordination cost and the service lateness cost are estimated considering simplified drivers.

Let us assume a supply stage with m suppliers (s_i, i =1,…,m) and n customers (c_j, j=1,…,n) where q_{ij} is the average quantity of products flowing from s_i to c_j, during each time period and $d(s_i c_j)$ is the distance between s_i and c_j.

3.1 Transportation cost evaluation

The transportation cost, TC, in each time period is evaluated as:

$$TC = c_t \cdot L \qquad (1)$$

where L is the total distance covered to deliver products for each time period in the supply stage and c_t is the unitary transportation cost. L depends on the coordination policy adopted and on the following assumptions. The transportation vehicles are always available with load capacity equal to C. When delivery is completed, the transportation vehicle is assumed to come back to the supplier's process from which it started. All products flowing from suppliers to customers can be loaded in the same vehicle and qij can be split out in units of product.

No collaboration

Adopting this policy for each supplier s_i and customer c_j, it results:

$$Y_{ij} = 2 \cdot d(s_i c_j) \cdot \mathrm{int}_{\sup}\left(\frac{q_{ij}}{C}\right) \qquad (2)$$

where Y_{ij} represents the distance covered to convey products from s_i to c_j by means of direct trips. In this policy the total distance covered results:

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[2] The Supply Chain Council has developed the SCOR model for evaluating the performance requirements of partner firms in a supply chain.

$$L = \sum_{i=1}^{m} \sum_{j=1}^{n} Y_{ij} \qquad (3)$$

Supply-centered collaboration

For this policy, a two-step algorithm is proposed.

First step (direct trips)

For each supplier s_i and customers c_j, it results:

$$Y_{ij} = 2 \cdot d(s_i c_j) \cdot \text{int}_{\text{inf}}\left(\frac{q_{ij}}{C}\right) \qquad (4)$$

where Y_{ij} represents the distance covered to convey products from s_i to c_j by means of direct trips with full vehicle load. If $\frac{q_{ij}}{C}$ is not an integer number, then for the remaining products that have to be delivered from s_i to c_j internal consolidation applies. The total distance covered in the first step is:

$$L_{DT} = \sum_{i=1}^{m} \sum_{j=1}^{n} Y_{ij} \qquad (5)$$

Second step (internal consolidation)

For each supplier with only one customer remaining to be supplied, direct trips occur. Then, let us consider each s_i with at least two customers to be supplied.

For the internal consolidation, si starts the first trip for supplying the customer farthest from it (cf). If two or more customers are the farthest from si, si starts internal consolidation from the customer with the greatest amount of product to be delivered. Successively, the internal consolidation involves the customer whose needs allow to reach the vehicle load capacity (if it exists) or the closest to cf and so on, until reaching the vehicle load capacity. If two or more customers are the closest to cf, the internal consolidation continues involving the customer with the greatest amount of product to be delivered.

The internal consolidation routine continues since at least two customers have to be supplied, also if the vehicle loading capacity is not reached.

Let $ICDs_ic_f$ be the total distance covered for all the trips needed to supply customers adopting the internal consolidation routine, starting from c_f. Two conditions can hold:

If $$ICD_{s_i c_f} + d(s_i c_h) \cdot 2A < \sum_{\Gamma_{s_i}} d(s_i c_j) \cdot 2 \qquad (6)$$

then, internal consolidation applies, where c_h is the customer which may remain to be supplied after the internal consolidation routine has been completed, Γ_{s_i} represents the set of customers involved in the internal consolidation routine, $A = \text{int}_{\text{sup}}\left(\frac{q'_{ih}}{C}\right)$, q'_{ih} is the quantity of products to be supplied to the last customer once the internal consolidation routine has applied. The quantity of product that cannot be delivered through internal consolidation ($\hat{q}_{ih}$) is delivered through direct trips.

If $ICD_{s_i c_f} + d(s_i c_h) \cdot 2A \geq \sum_{j=1}^{h} d(s_i c_j) \cdot 2$ (7)

then, only direct trips between s_i and c_f occur. So, repeat the second step considering the remaining customer closest to s_i.

The distance covered in the second step is L_{IC}, which is the total distance covered to deliver products by means of internal consolidation routine and potential direct trips. Then, in the supply-centered collaboration policy the total distance covered results:

$$L = L_{DT} + L_{IC} \quad (8)$$

Total collaboration

For this policy a three-step algorithm is proposed

First step (direct trips)

The first step is the same as in the supply-centered coordination policy.

Second step (internal consolidation)

The second step is the same as in the supply-centered coordination policy except the quantity of products that cannot be delivered through internal consolidation ($q_{ij}^{'}$). In fact, in this case, it can be delivered through external consolidation.

Third step (external consolidation)

Let us start the external consolidation routine from the supplier s_i with the greatest q_{ij}. Let us find the suppliers s_k with remaining products $q_{kj}^{'}$ to be delivered to the customer c_j shared with s_i. Among these suppliers let us consider the closest to s_i. The routine may involve two or more suppliers since reaching the vehicle load capacity or consolidating all the suppliers. If it involves more than two suppliers let us consider the supplier closest to s_k.

Let $ECDs_i$ be the total distance covered in order to supply all customers adopting the external consolidation routine, starting from s_i. Two conditions hold:

If $ECD_{s_i} + d(s_z c_j) \cdot 2B < \sum_{i \in \Omega_{sc_j}} d(s_i c_j) \cdot 2$ (9)

then, external consolidation applies, where Ω_{sc_j} represents the set of suppliers with remaining products to be delivered to c_j after the internal consolidation routine, s_z is the last supplier having to supply c_j, $B = \text{int}_{\sup}\left(\frac{q_{zj}^{''}}{C}\right)$, $q_{zj}^{''}$ is the quantity of products to be supplied to c_j by s_z once the external consolidation routine has applied.

If $ECD_{s_i} + d(s_z c_j) \cdot 2B \geq \sum_{i \in \Omega_s} d(s_i c_j) \cdot 2$ (10)

then, direct trip between s_i and c_j applies. So, repeat the third step considering the second supplier with the greatest q_{ij}. Let us consider the case in which suppliers have no common customer. Then, if

$$d(s_i s_k) + d(c_h c_r) < d(s_i c_h) + d(s_k c_r) \quad (11)$$

and

$$q_{ij} + q_{kr} \leq C \tag{12}$$

external consolidation routine applies, involving s_i, s_k, c_h, and c_r, where s_i and s_k are the pair of closest suppliers; c_h and c_r are the customers to be supplied by s_i and s_k, respectively; else direct trips apply between s_i and c_h, and between s_k and c_r, respectively.

The distance covered in the third step is L_{EC}, which is the total distance covered to deliver products by means of external consolidation routine and potential direct trips. In the total collaboration policy the total distance covered results:

$$L = L_{DT} + L_{IC} + L_{EC} \tag{13}$$

3.2 Coordination cost evaluation

The coordination cost, CC, is evaluated as:

$$CC = c_c \cdot I_{CE} \tag{14}$$

where I_{CE} is the index of coordination effort and c_c is the unitary coordination cost. I_{CE} can be estimated as:

$$I_{CE} = \sum_{t=1}^{r} \frac{N_{Rt}!}{2! \cdot (N_{Rt} - 2)!} \tag{15}$$

where N_{Rt} is the number of service requirements coming from the suppliers and customers involved in the t-th trip to the 3PL in order to satisfy their needs; *r* is the total number of trips defined by the 3PL in each coordination policy.

3.3 Service lateness cost evaluation

The service lateness cost, SLC, is evaluated as:

$$SLC = c_s \cdot I_{SL} \tag{16}$$

where I_{SL} is the index of service lateness and c_s is the unitary service lateness cost. I_{SL} can be expressed as:

$$I_{SL} = \sum_i \sum_j \sum_t \left\{ \left[D(s_i - c_j) - d(s_i c_j) \right] \cdot \frac{\Delta q_{ij}}{q_{ij}} \right\}_t \tag{17}$$

where t is the generic trip that takes place when internal or external collaboration occurs; $D(s_i - c_j)$ is the distance covered to deliver products from s_i to c_j, in trip t; Δq_{ij} is the quantity of products delivered from s_i to c_j in trip t.

4 A CASE STUDY

The supply stage of a brickworks company has been considered as a case study. The stage consists of two brickworks production plants (s_1, s_2) supplying four building sites (c_1, c_2, c_3, c_4). The two production plants belong to the same company and each plant produces only one type of bricks. Plants and sites are located in the Southern Italy and the logistics service is managed by only one 3PL.

In Table 1 the distance (expressed in km) between suppliers and customers sites are reported.

Table 1. Distances [km] between suppliers and customers.

	s_1	s_2	c_1	c_2	c_3	c_4
s_1	0	10	80	75	110	90
s_2	10	0	85	90	100	85
c_1	80	85	0	15	30	25
c_2	75	90	15	0	30	35
c_3	110	100	30	30	0	15
c_4	90	85	25	35	15	0

The average quantities of bricks (expressed in pallet) flowing each day from suppliers to customers have been estimated and are shown in Table 2.

Table 2. Average quantities [pallet] of product flowing each day from production plants to building sites.

	c_1	C_2	c_3	c_4
s_1	15	11	20	10
s_2	7	14	14	20

Transportation, coordination, and service lateness costs of this supply stage are evaluated according to the previously developed model. In Table 3, results are shown for C = 18 pallets.

Table 3. Costs evaluation for different coordination policies.

Coordination policy	**Transportation cost**	**Coordination cost**	**Service lateness cost**	**Total cost**
No collaboration	$1820c_t$	$8c_c$	0	$1820c_t+8c_c$
Supply-centered collaboration	$1465c_t$	$12c_c$	$38c_s$	$1465c_t+12c_c+38c_c$
Total collaboration	$1365c_t$	$19c_c$	$111c_s$	$1365c_t+19c_c+111c_c$

The results show that moving from no collaboration to total collaboration transportation cost decreases. This reduction is due to the adoption of internal consolidation, in the case of the supply-centered collaboration, and of both internal and external consolidation, in the case of total collaboration. Nevertheless, coordination and service lateness costs increase. Then, even if total coordination brings to lower transportation cost, its adoption has to be subordinated to the evaluation of the coordination effort required and to the lack of service responsiveness. Consequently, trade-offs have to be considered. Being the supply stage characterised by specific unitary costs (ct, cc, cs), using this approach the 3PL can evaluate which coordination policy is more suitable to be used in order to organize the market. However, the different coordination policies are based on the collaboration among the actors, which cannot be necessarily achieved. In fact, for instance, actors, such as customers, can decide to do not collaborate, because the service lateness, in terms of lack of responsiveness, can contrasting their own interests. Then, it is important to identify what can occur when customers do not collaborate. In the case study, we compare the costs in the case of total collaboration policy with the case when a single customer affected by service lateness decides to do not collaborate. For these customers, the service lateness related to the delay in delivering products is avoided adopting direct trips. In the total collaboration scenario, assuming no collaboration for only one customer at time, different collaborative scenarios can result. In Table 4 the supply stage costs for each scenario are shown.

Table 4. Supply stage costs in different collaborative scenarios.

Collaborative scenario	Transportation cost	Coordination cost	Service lateness cost	Total cost
Total collaboration without c_1	$1465c_t$	$15c_c$	$35c_s$	$1465c_t+15c_c+35c_c$
Total collaboration without c_2	$1435c_t$	$19c_c$	$82c_s$	$1435c_t+19c_c+82c_c$
Total collaboration without c_4	$1535c_t$	$17c_c$	$109c_s$	$1535c_t+17c_c+109c_c$
Total collaboration	$1365c_t$	$19c_c$	$111c_s$	$1365c_t+19c_c+111c_c$

In these scenarios supply stage's costs change. In particular, the transportation cost increases, the service lateness cost decreases, and the coordination cost is at least the same respect to the total collaboration scenario. Let us consider that the service lateness cost for the not collaborative customers is equal to zero. However, in this case it seems reasonable that the unitary transportation cost will increase for this customer, because of the growing of the supply stage's cost. Then, a customer may decide to be collaborative or not according to the trade-off between ending and rising costs.

5 CONCLUSIONS

In the paper the notion of organized logistics services markets has been provided referring to a supply chain stage. The organization is achieved by means of coordination policies, based on the consolidation of logistics flows and on the collaboration among the actors of the supply stage.

A model for evaluating the trade-offs between the benefits and the costs of the coordination policies (namely no collaboration, supply-centered collaboration, and total collaboration) and the influence of each collaboration level has been developed. This approach permits to explore the opportunities to enhance logistics service performance as the degree of collaboration among actors of a supply chain increases. It is useful to highlight that the model is based on a heuristic algorithm, which has shown to be effective for the examined cases.

In particular, the model has been applied to an Italian brickworks company in order to analyse the transportation, coordination, and service lateness costs for each coordination policy. Moreover, different collaborative scenarios (partial and total) have been investigated and compared. The model suggests which actor of the supply stage can get benefit or cost for not collaborative behaviour. Then, a rational approach for negotiation is provided.

This model can constitute the conceptual base to create the frame of analysis for the designing and managing of logistics services markets.

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