Collaboration Mechanism for Shared Returnable Transport Items in Closed Loop Supply Chains

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Abstract: This paper addresses a relevant practical approach of collaboration in supply chains including reverse flows of materials. The objective is to simulate a two-stage closed loop supply chains in which two producers use reusable pallets to distribute their finished products to the same retailers. The producers supply raw materials and new pallets they need from suppliers. For each producer, the flows of raw material, loaded/empty pallets and finished products are triggered by information flows. Two simulation models are considered. In the first model, supply chains are non-collaborative. Each producer manages his own pool of pallets. After receiving replenishment orders, trucks deliver loaded pallets and simultaneously pick-up empty ones from retailers to be returned to the producer. In the second model, the two producers share their pool of empty pallets. The results show that collaboration can lead to economies of scale and costs reduction. They also highlight the need for a third party to manage the entire system to promise mutual benefits for the concerned parties.

1 INTRODUCTION

A supply chain consists of a set of players including raw material suppliers, manufacturers, wholesalers, carriers, distributors and retailers. These entities are involved in a series of processes and activities to get a product or service to the customer. Supply Chain Management (SCM) is generally recognized as the biggest source of benefits for organizational activities. It has also been the subject matter of many papers in research literature in the fields of operations management, operations research and economy since supply chains are getting more complex.

Until now, to counteract complexity in supply chains, the management emphasis has been on exchanging information and coordinating the flow of products between organizations. This is no more enough to cope the increasing customer expectations, the trend of online shopping and the pattern of strongly individualized customer demand. The growing complexity of most services and products requires the use of more advanced (and costly) resources. These resources can profit from large economies of scale, which can be better caught if resources are shared between organizations. The next logical step is no longer focus only on coordinating products and information flows, but also on sharing assets in order to obtain maximum efficiency.

Increased concerns about the environmental impact give rise to the emergence and the development of the concept of closed-loop supply chains (CLSC). A closed-loop supply chain consists of both traditional forward activities and additional return flow processes. The return flow under study in this paper concerns Reusable Transport Items (RTI). RTI consist of all means used to assemble goods for transportation, storage, handling and product protection in a supply chain that returns goods for further usage (Iassinovskaia, et al., 2016). Examples include pallets as well as all forms of reusable crates, trays, boxes, barrels, trolleys, pallet, etc.

As RTI are by their very nature reusable, they flow in a closed loop within the supply chain: they can be collected and returned empty to the sender, or they can be reused by the receiver so that he can in his turn ship his products. Therefore, there exist two types of flows that must be managed simultaneously (Talaei and al., 2016): forward flows, which correspond to the traditional distribution of goods loaded on RTI, and reverse flows, which correspond to the picking up of empty RTI. Players act as independent intermediaries to manage the processing of flows between manufacturers and distributors via logistics service providers (LSPs). This management requires tools for identifying assets, centralising information flows, planning of production, delivery and pick-ups, synchronisation of operations according to the requirements of each actor, tracking and traceability of products. This centralisation of flows enables the pooling of services and resources with a perspective of sharing between several actors.

The management of RTI is still far from being controlled. The challenges are enormous given the costs of managing froward and reverse flows, sorting, handling and costs due to losses. The drive for cost reduction coupled with the willingness (not to say the constraint) to track assets makes auxiliary resources such as RTI a crucial issue that can impact the performance of the whole supply chain. Indeed, a stock shortage of these RTI or a delay in the supply or in the return leads to a delay in production or even an interruption of product flows, with all the consequences that this entails. In addition, their mismanagement lengthens lead times and encourages players to over-invest in these assets. Their difficult identification increases idle inventory and counterfeiting. In addition, their mishandling impairs the quality of the products shipped. Finally, the key players in the chain, in a growing concern to participate in sustainable development, are concerned about controlling natural resources and preserving the environment, by promoting sharing RTI, which considerably reduces the costs of storage, stock-outs, and the production of packaging waste.

Consequently, companies are increasingly wondering the possibility of joining their forces and sharing their RTI assets to develop an unsurpassably competitive advantage. Sharing RTI can boost the competitiveness of the entire supply chain while decreasing the cost of sourcing, inventory and transportation. The consequent savings allow players to achieve higher outcomes.

The main objective of this paper is to provide a what-if analysis of a two-stage closed loop supply chains where two non-competing manufacturers deliver their products using compatible, similar and smart RTI to a network of common retailers. A simulation approach is used to quantitatively evaluate the pros and cons resulting from collaboration and RTI sharing.

The remainder of the paper is organized as follows. The related literature is briefly reviewed in section 2. The problem is described in section 3. In section 4 the experimental design is provided, and the results are presented in section 5. Section 6 concludes the paper recalling the major's takeaways and research perspectives for further research in this area.

2 RELATED WORK AT GLANCE

Collaboration among companies is classified by using certain characteristics.Direction (vertical/horizontal), time horizon (short/middle/long term), functional cooperation (joint functions vs. complementary functions), degree of legal arrangements (from formal contracts to informal agreements), and the number of involved parties (Freitag et al. 2016).

Regarding direction there exist three types of collaboration: Vertical, Horizontal and Lateral collaboration. The term supply chain management refers to vertical collaboration and integration among parties in different levels of a supply chain. "*The key drivers of cost savings are inventory and transport reduction, logistics facilities or equipment rationalization, and sharing information*" (Cruijssen, 2006). Vertical cooperation includes for example Collaborative Planning, Forecasting and Replenishment (CPFR), Vendor Managed Inventory (VMI), etc. Horizontal collaboration takes place between companies operating at the same level of the supply chain. Some examples of application are Manufacturer Consolidation Centers (MCCs), joint route planning, and purchasing groups. Co-opetition is a variant of horizontal cooperation. It takes place when enterprises are simultaneously cooperating and competing. It concerns no-core activities while competition remains unchanged for core activities (Bengtsson and Kock, 1999). Finally, lateral cooperation is defined as a combination of vertical and horizontal cooperation (Simatupang and Shridharan, 2002). It aims at gaining more flexibility by combining and sharing capabilities in both vertical and horizontal directions.

According to (Freitag et al. 2016), physical assets sharing turns out to be a new type of collaboration and the most flexible one, while the contractual complexity of the required legal regulations between the companies is kept low. It can be a short, mid- to long-term collaboration and be set up either vertically, horizontally or laterally. Basically, every

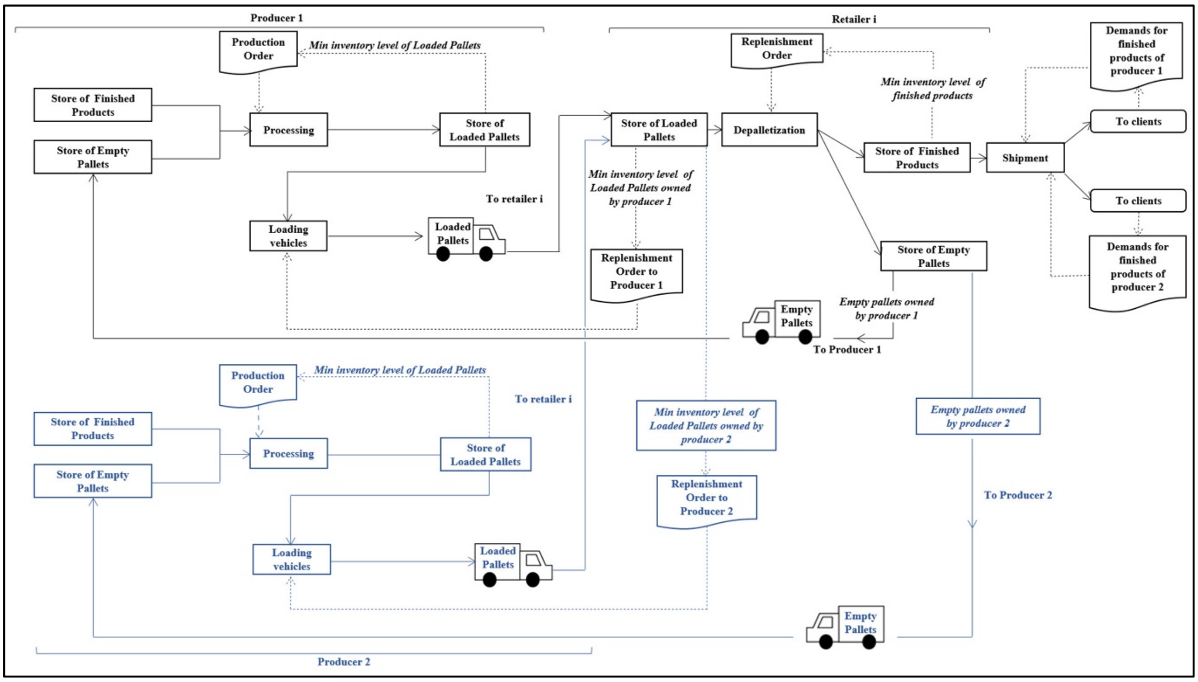

Figure 1: Simulation modelling flowchart of a two-stage closed loop supply chain.

asset can be sharable, e.g., machine, warehouse, transport means, returnable transport items (reusable pallets, boxes; crates, etc.), production line, etc.

The most closely aligned work with this paper is the research stream that addresses physical assets sharing particulary RTI as a part of horizontal collaboration. (Reaidy, et al. 2015) and (Makacia, et al. 2017) study collaborative warehousing schemes. (Yilmaz, Savasaneril, 2011), (Pan, et al. 2019) and (Wang, et al. 2018) examine transportation resource sharing between independent and non-competing companies. (Mlinar, Chevalier, 2016), (Becker, Sterna, 2016) and (Khajavi, Holmström, 2017) investigate machinery and production capacity pooling. As for RTI, all papers address the problem as a part of VMI and/or develop decision supports models for costs reduction within a stochastic or deterministic environment. An example of application can be found in: (Kim, et al. 2014), (Cobb, 2016), (Iassinovskaia, et al. 2016).

As far as we are concerned, this literature review shows that few papers exist that evaluate the performance of sharing physical assets between different supply chains let alone in closed loop supply chains and in managing the so-called returnable transport items. Indeed, most of the paper address problems where coordination is based either on sharing of information or on joint decision-making. This paper addresses a relevant practical approach of horizontal collaboration in closed loop supply chains including sharing returnable transport items.

3 PROBLEM DESCRIPTION

Simulation has been identified by numerous authors as an effective tool to evaluate collaboration mechanism design in supply chain (Pirard, et al 2011). This technique makes it possible to take into account the complexity and the dynamic behavior of a system and to consider the uncertainty related to its environment (e.g. customer demand, lead time). Simulation also enables the decision maker to evaluate several control policies. Numerous replications of the simulation model, corresponding to many possible situations, can be carried out in order to evaluate the robustness of the considered design. Simulation does not guarantee an optimal design. However, this technique offers the manager real help in establishing and in evaluating the consequences of his decisions. We devote the reminder of the paper to explain the simulation model we developed in order to highlight the benefits of promoting RTI sharing. The advantages of economies of scale can be viewed in terms of cost savings and better operational performance. The supply chain players can achieve a higher service level at lower costs if they agree on a suitable collaboration mechanism.

In this paper we study a two-stage supply chain in which two non-competing manufacturers deliver their products to a network of common retailers using compatible, similar and smart RTI, namely pallets.

The simulation model we be built captures the supply chain physical entities at the different levels, the material and information flows between entities and the different decisions made at each level by each manufacturer or retailer. The architecture of the simulation model that corresponds to the two-stage supply chain is depicted in figure 1. When a retailer receives information on the demands of his customers, he checks whether his stock of non-palletized finished products is enough to meet them. If not, he depalletizes the stock of loaded pallets. If the stock reaches its replenishment point, or a new demand has unmet finished product requirements, he sends a replenishment order to a producer. When a producer receives this order, he checks whether his stock of finished and palletized products is enough to satisfy the demand of his customer. If the quantities requested exceed the available quantities, the producer releases a production order. In the same veins, at the level of each producer if the quantity of raw material or the quantity of empty pallets is less than a minimum inventory, a producer sends a replenishment order to suppliers. Thereafter, the trucks, loaded with the ordered pallets, leave the depot and visit retailers to deliver loaded pallets and simultaneously collect a quantity of empty pallets -as long as the capacity of trucks is not exceeded.

We evaluate two scenarios. The first corresponds to the non-sharing case. Each producer manages separately his own pool of pallets. When a producer (manufacturer) receives replenishment orders from retailers, he puts trucks on way to deliver loaded pallets and simultaneously pick-up his empty ones to be returned. Empty pallets are stored separately at the retailer location.

We consider a second case where the two producers can share their pool of empty pallets. The pallets are considered to be substitutable and there is no need to keep them in sperate storages at costumer locations. The quantity of empty pallets, collected by each producer's trucks, is whenever possible equal to the quantity of full pallets delivered. In terms of profits sharing, we suppose that each partner pays a certain amount of dollars for each pallet used and owned by the other producer. The damage of the pallets is also supported. Each producer pays a penalty cost per damaged pallet.

In a previous work (Iassinovskaia, et al. 2016), we have studied a two-stage supply chain where non-shared RTI are used to protect and distribute products from a manufacturer to a set of customers. We modelled the problem as a pickup and delivery inventory-routing problem. We formulated a mixed-integer linear program (MILP) taking into consideration different constraints inherent in transport, routing construction, truck and inventories capacity and demand satisfaction. The objective function to optimize is a combination of transportation costs, inventory costs of empty and loaded RTI at customers and at the depot, maintenance costs and the cost to buy new RTI.

We have extended the scope of the problem to include a set of manufacturers and developed a mathematical model for solving an inventory routing problem where RTI are shared between manufacturers (Achamrah, et al. 2019). In the present contribution, we would like to extend the scope of the problem to focus on the global loss of efficiency that supply chain players may experience. This can be induced by the distributed nature of their decision structure and their independent- not to say conflicting objectives and way of operating that may hinder the search a win-win agreement. Simulation makes it possible to take into account the complexity and the dynamic behavior of the system and to consider the uncertainty related to its environment (e.g. customer demand, lead time at each level).

4 EXPERIMENTAL DESIGN

We consider two manufacturers who manage independently their pool of pallets and deliver to the same set of 9 retailers. The simulation horizon corresponds to 7 days. Trucks have a similar capacity of 20 pallets to be loaded. Each pallet contains 8 boxes filled with finished products. The different pallet storage locations have been designed with a capacity of 1000 in terms of number of pallets. The same goes for holding capacities of finished products at the level of each producer and retailer.

A replenishment order for each retailer is an inventory level less than or equal to 5 in terms of the number of loaded pallets. As for manufacturers, the replenishment order regarding empty pallets is an inventory level less than or equal to 10. And the replenishment order regarding raw material is an inventory level less than or equal to 15. For both producers, the order production point is an inventory

Table 1: Service level at the level of producer 1 and producer 2 for each scenario under consideration.

-	Producer 1				Producer 2			
	# of new purchased pallets	Lost sales	Satisfied demands	Service level (%)	# of new purchased pallets	Lost sales	Satisfied demands	Service level (%)
Non-collaborative supply chains	924	288	874	75.2	1123	284	906	76.1
Collaborative supply chains	690	105	1057	91.0	852	86	1104	92.8

Table 2: Service level at the level of retailer 1, 2 and 3 for each scenario under consideration.

	Retailer 1			Retailer 2			Retailer 3		
	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2
Non-collaborative supply chains	1007	945	48.4	188	567	75.1	286	526	64.8
	10	902	98.9	475	2035	81.1	206	942	82.1
Collaborative supply chains	318	1634	83.7	111	644	85.3	199	613	75.5
	912	912	100.0	80	2430	96.8	0	1148	100

level less than or equal to 4 in terms of the number of loaded pallets.

At the level of each retailer depalletization order corresponds to an inventory level of finished products less than or equal to 5. The demand the retailers have to satisfy is assumed to be a random variable with a normal distribution of mean of 13 and standard deviation of 2 in terms of the number of finished products of the producer 1 and a normal distribution of mean of 20 and standard deviation of 2 in terms of finished products of the producer 2. Palletization order at the level of each producer corresponds to an inventory level of loaded pallets less than or equal to 10. At the beginning of the simulation, the initial inventory level of empty pallets at producer 1 is equal to 30 and equal to 35 at level of producer 2. The initial inventory level of finished products at producer 1 is equal to 90 and equal to 60 at level of producer 2. The initial inventory level of raw material is equal to 40 at the producer 1 and to 30 at the producer 2. The initial inventory levels of empty pallets and finished products at the level of each retailer are equal to zero; For both producers and retailer, the initial inventory level of loaded pallets is equal to zero;

For both producer the cost to buy a new pallet is \$15/pallet. In terms of profits sharing, we suppose that each producer pays \$1.5 per period for each pallet used and owned by the other producer. Each producer pays \$3 per unowned and damaged pallet. Lost sales cost of \$8 associated to each unsatisfied demand at level of each producer.

5 ANALYSIS AND DISCUSSION

To assess each scenario, we selected the following criteria: (1) Lost sales in terms of the number of filled pallets at the level of each producer and in terms of the number of boxes at the level of each retailer ; (2) Satisfied demands in terms of the number of filled pallets at the level of each producer and in terms of the number of boxes at the level of each retailer; (3) Service level at each producer and retailer; (4) Cost to buy new pallets; (5) the savings, loss and pay-out at level of each producer.

All the simulation steps have been performed on a personal laptop computer (Windows10, Intel Core i5, 2.4GHz, 4GB of RAM) and with FlexSim 19.2.3.

Table 3: Service level at the level of retailer 4, 5 and 6 for each scenario under consideration.

-	Retailer 4			Retailer 5			Retailer 6		
	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2
Non-collaborative supply chains	331	571	63.3	46	170	78.7	325	364	52.8
	139	245	63.8	289	134	31.7	88	522	85.6
Collaborative supply chains	98	804	89.1	19	197	91.2	268	421	61.1
	37	347	90.4	124	299	70.7	73	537	88.0

Table 4: Service level at the level of retailer 7, 8 and 9 for each scenario under consideration.

-	Retailer 7			Retailer 8			Retailer 9		
	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2	Lost sales Product 1 Product 2	Satisfied demands Product 1 Product 2	Service level (%) Product 1 Product 2
Non-collaborative supply chains	184	571	75.6	279	841	75.1	255	2435	87.3
	91	333	78.5	498	1960	79.7	258	164	86.3
Collaborative supply chains	144	611	80.9	211	909	81.2	175	2615	93.7
	42	382	90.1	102	2356	95.9	31	391	92.7

The number of replicate simulations is equal to 100. We analyse the effectiveness of the mechanism under consideration assuming the following assumptions:

- All the empty pallets present in the inventory at the end of a period can be reused in the next period;
- 10% of pallets returned from retailers in each period are considered damaged (unrepairable);
- Routing of trucks are not optimized and are randomly constructed;
- Processing time required for palletization at the level of each producer includes the time necessary for sending replenishment orders to suppliers and for receiving the ordered quantity of new pallets and also the time to palletize finished products.

As mentioned earlier, in this paper we consider two producers who manage independently their pool of pallets and deliver to the same set of retailers. After receiving a replenishment order, they deliver loaded pallets to a set of 9 retailers and collect simultaneously empty pallets. The mechanism thereafter by which the collaboration is established between the two producers is examined.

Table 1, 2, 3 and 4 summarize the results of simulation for all cases under consideration.

As we can notice and taking into account the 10% of pallets damaged at each period, sharing pallets allows both producers to reduce the number of pallets bought from suppliers. Indeed, each producer can replace the same quantities of new empty pallets he needs to palletize by the substituted quantities of empty pallets of the other producer. As a result, the service level is enhanced. Furthermore, sharing allows them to deliver more loaded pallets to retailers (the number of the replenishment orders is increased) and hence, enhance the service level at the level of each retailer. It also enables to increase processing time. Indeed, this processing rate includes, in addition to the time required for palletization, the time required for each producer to send replenishment orders to suppliers and to receive the ordered quantity of new pallets. Since each producer can use the other's

Table 5: Breakdown of costs at the level of producer 1 and 2 for each scenario under consideration.

Cost break down ($)	1st scenario: non-collaborative supply chains		2nd scenario: collaborative supply chains (sharing pallets)	
	Producer 1	Producer 2	Producer 1	Producer 2
New pallets cost	13 860	16 845	10 350	12 780
Saving (regarding the purchased pallets)	-	-	3 510	4 065
Pay-out (include the costs resulting from the use and/or the damage of unowned pallets)	-	-	3 455	4 639.5
Lost sales	2 304	2 272	840	688
Saving (regarding buying new pallet and the lost sales)	-	-	4974	5649
Gain			334.5	2 194

pallets, he does not always have to buy the pallets from the supplier each time his stock of empty pallets reaches its replenishment point. Thus, processing time is spent more on palletizing. This means that palletizing and responding to retailers' replenishment orders can be done faster and more efficiently.

Table 5 gives more insights on the efficiency of pallets sharing. The saving, loss and pay-out are deducted according to the profit-sharing policy adopted in this paper.

From the table 5 we notice that by minimizing the number of pallets bought, sharing pallets allows both producers to realise economies of scale and reduce the cost of purchasing new pallets as compared to the first scenario. As the one can see, producer 2 benefits more from sharing as compared to the producer 1 ($2 194 vs $334.5). Therefore, for a better coordination and profit allocation, it would be convenient to call upon a third-party service provider to manage the whole system. Indeed, if a player would be in charge of deliveries and pick-ups, inventory and transport costs and the resulting carbon footprint would be reduced. In this way, all parties including the suppliers would benefit from the gains. Regarding the share of information flows, if a player exists, he would manage all the inventories and replenishments orders. Then, he would synchronize the different flows so that the inventory cost at all levels would be reduced. Future studies can help to understand the impact of the presence of a player on the performance and behaviour of collaborative supply chains.

6 CONCLUSIONS

This paper addresses the issue of sharing physical assets between independent producers in a two stages supply chain. We design a simulation model to investigate different ways players can manage their reusable transport items within a closed loop supply chain. The model compares two cases. The first case considered two producers working autonomously and delivering their finished products using pallets to the same retailers. The second scenario considers sharing the pool of empty pallets between producers as a mechanism of collaboration. Material and information flows, the inventory and transportation costs at the level of each producer are analysed and assessed in order to get insight on the effectiveness of coordination. The result of simulation shows that the coordination lead to economies of scale and cost reduction. It also rises the need for a third party to manage the whole system for promising mutual benefits to the members.

Our future research plans include studying the effect of resources sharing in a more complex supply chains where uncertainties and risks are exposed, and cooperative games are analysed using shapely value for example which may allow to assess different collaboration mechanisms starting from sharing information to sharing trucks, warehouses and machineries. On the other hand, managing the whole supply chains and evaluating the performance of supply chain requires a player. Various scenarios may be explored with the help of simulation.

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