COLLABORATIVE TRANSPORTATION MANAGEMENT TO IMPROVE SUSTAINABILITY: A CASE STUDY

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ABSTRACT: *Collaborative supply chains have become recently an important element for many companies to improve their supply chain efficiency. Moreover, to be competitive in industrial world, the implementation of collaborative supply chains should give positive effect that can be related to sustainable development. In this paper, we deal with collaboration among shippers in less than truckload transportation. We propose a mixed-integer linear model to pool supply chains by adding two hubs between suppliers and customers in order to reduce the distance and consequently the greenhouse gas emissions. In addition in the model, we allow multi-picking and multi-delivering to optimize the filling rates of the trucks. This model is tested with a case study with real data from two agri-food companies delivering customers all over Europe. With this model, we are able to reduce the total distance travelled and the total amount of emissions.*

KEYWORDS: *Collaboration, Sustainability, Supply chains, Routing, Consolidation.*

1. INTRODUCTION

Over the past decade, firms have adopted supply chain management as a critical element of their corporate strategies, but many firms do not realize the anticipated benefits of constructing collaborative operating relationship with supply chain partners. The term collaboration has taken on several interpretations when used in the context of supply chain management. The term supply chain collaboration refers to those activities among and between supply chains partners concerned with the cost effective, timely, and reliable creation and movement of materials to satisfy customer requirement (Muckstadt *et al.*, 2001). Despite the barriers that potentially deteriorate collaboration among companies for many industries all over the world, collaboration is becoming more of a necessity than an option. Kinds of collaboration namely vertical, horizontal and lateral collaboration, (Simatupang and Sridharan, 2002) are implemented in several relationships even partnership in supply chains.

Nowadays, the implementation of collaborative supply chain becomes necessary in all industrial sectors. To be competitive in industrial world, the implementation of collaborative supply chain should give positive effect that can be related to sustainable development. Becoming sustainable has become a non-negotiable imperative for many organizations. Apart from the regulatory requirements, pressures from various stakeholders, interest groups and international bodies has made it imperative that organizations balance environmental and societal impacts with economic necessities. Sustainable business management emphasizes minimum impact on the natural world and maximum benefit for society. Collaborative supply chain that is concerned on sustainable development is a complex system but have a great influence to viability of an industry.

Collaboration is about organizations and enterprises working together and can be viewed as a concept going beyond normal commercial relationship. It is a departure from the anchor point of discreteness, which underlines spot market transactions to a relational exchange, as the roles of supplier and buyer are no longer narrowly defined terms of the simple transfer of ownership of products. Collaboration appears as enterprises recognize cases where working and operating alone is not sufficient to resolve common problems and to achieve the desired goals (Barrat and Oliveira, 2001; Corbett *et al.*, 1999; Huxham, 1996 and Wagner *et al.*, 2002). Collaboration between supply chain partners is one of the issues which lately has received increased attention in the supply chain literature (Andraski and Di Yeso, 2003 and McCarthy and Golicic, 2001) in addition to attention received in the past in the strategic management literature (Spekman and Sawhney, 1995).

Two pillars are distinguished in the framework for supply chain collaboration, which are dealing with the design and the government of supply chain activities, and the establishment and the maintenance of supply chain relationships, respectively (Matopoulus *et al.*, 2007). The pillars can essentially be applied either in vertical, horizontal and lateral collaboration. The first pillar in the framework is related to the design and government of supply chain activities consisting of three elements. The first is about taking the decision of selecting the appropriate partner. The second element involves selecting activities on which collaboration will be established. After selecting activities the third element is to identify at which level companies will collaborate. The combination of the three elements comprises the intensity of collaboration. The more the depth (from operational to tactical and strategic), the width (from simple supply chain activities to more complexes such as new product development and the number of entities) the more intense collaboration is. Finally, another important element for the design and governing of supply chain activities includes the decision of selecting the appropriate technique and technology to facilitate information sharing. The second pillar concerns the establishment and maintenance of supply chain relationships. It includes the less tangible, but equally important, element of relationships. The critical elements that have been also cited in the literature include mutuality of benefits, risk, and reward sharing (Barrat and Oliveira, 2001).

Despite the benefits that have been identified in collaboration among companies, collaborative practices may not be appropriate for every business relationship (Krause, 1999). In fact, apart from the benefits, risks are also involved in collaborations. One of the most obvious risks in collaboration is the risk of failure. The risk of failure includes the loss of significant investments in money, time and delay or abandonment of business plans, in cases where collaboration is unsuccessful. In addition, an inherent risk to the risk of failure is the exposure to competition. Indeed, companies should bear in mind that the potential collaborator may become at some point in time the partner of another competitor. Another important risk is related to the potential increased dependence of one actor. This is the more complex issues in business relationships. In fact, many authors (Adams and Goldsmith, 1999 and Spekman and Sawhney, 1995) have argued that in the process of procurement for example, the more a buyer buys from a supplier, the more likely the buyer will be able to influence the supplier. In most of the cases in the literature, dependence has been viewed as a risk, which is particularly high for small companies collaborating with big ones, especially when combined with the element of power. Furthermore, an inherent risk associated to collaboration is the risk of increasing operational complexity.

After reviewing some models dealing with collaboration in transportation, we present a model for pooling supply chains with multi-pick and multi-delivery. Then we present a case study based on this model and finally we discuss about the results.

2. COLLABORATIVE TRANSPORTATION IN THE LITTERATURE

The increasing fuel prices and the fierce market competition make more and more urgent for transportation companies to improve their transportation planning. The collaboration among the companies is an effective way for them to achieve this goal, which gives rise to the topic of collaborative transportation. Most of the paper in the literature are based on the vehicle routing problem and propose models for the operational level of the supply chain. In Audy *et al.* (2007), a framework is proposed to describe collaboration in transportation and describe strategic, tactical, operational and real-time transportation planning decisions and raise issues about implementing collaborative decision processes. Kopfer and Krajewska (2007) present an overview and a comparison of existing approaches for an integrated transportation and forwarding problem. D'Amours and Ronnqvist (2010) give a survey of previous studies in the field of collaborative logistics. They first present opportunities in collaborative planning, and then discuss main issues in information and decisions technologies.

There are several points of view for the collaborative transportation problem. First, the shippers can collaborate together to minimize their costs. In fact, shippers are exposed to shorter and shorter customers' lead-time and have to send more often less quantities of product. In this context of less than truckload transportation, they can collaborate with other shippers to propose common shipments to a carrier to minimize their transportation costs. Shippers that provide full truckload can also collaborate to minimize empty backhauling to the carrier.

There are few works on shippers' collaboration problem. Ergun *et al.* (2007a and 2007b) formulate this shipper collaboration problem as a lane-covering problem (LCP), which is covering a subset of arcs in a directed Euclidean graph by created constrained cycles of a minimum cost. They also present and study a variant of the LCP, the cardinality constrained lane covering problem, in which the number of arcs in each cycle is less than a predefined number and another version of the LCP to solve the shipper collaboration problem: the time-constrained lane covering problem. Yilmaz and Savasaneril (2012) propose a model for less than truckload shipper collaboration problem. After describing the behaviour of the shippers in the collaboration, they propose two methods for allocating cost-benefits. In Pan *et al.* (2013), the flows between two stages of supply chain are pooled. Before pooling, flows from suppliers go directly to distribution centre. After pooling, upstream or downstream hubs can be created. Flows can go from upstream hubs to downstream hubs, from upstream hubs to distribution centre or from suppliers to downstream hubs. Some direct flows can be conserved. They formulate a model for this problem at a

Authors	Hubs	Routing	Multi-product	Time windows	Profit share	Objective function	Method
Dai and Chen (2012)		X	X			Cost (Linear)	Lagrangian relaxation
Ergun et al. (2007a)		X		X		Cost (Linear)	Heuristics
Ergun et al. (2007b)		X				Cost (Linear)	Greedy Algorithm
Hernandez et al (2011)		X				Cost (Linear)	Branch-and-cut algorithm
Liu et al. (2010)		X				Cost (Linear)	Two-phase heuristic
Pan et al. (2010)	X		X			CO_2 Emissions (piecewise linear)	Exact method
Yilmaz and Savasaneril (2012)					X	Cost	Game theory approach
Our approach	X	X	X			CO_2 Emissions (piecewise linear)	Exact method

Table 1 Characteristics of collaborative transportation management models

strategic level considering greenhouse gas emissions, and two modes of transportation, rail and road. Their goal is to minimize the total gas emissions of the network and solve the problem with CPLEX.

Another problem in collaborative transportation is the carriers' collaboration problem. Carriers' collaboration considers how carriers can reduce costs by sharing their vehicle capacities and transportation tasks, given the tasks that they have to serve. In less than truckload transportation, collaboration can optimize load of the trucks. In full truckload transportation, collaboration can minimize backhauling.

Liu et al. (2010) propose a model for a carrier collaboration system called the multi-depot capacitated arc routing problem with full truckloads. Hernandez et al. (2011) propose a model for a small-to medium-sized less-than-truckload carrier collaboration problem under dynamic capacities. They first describe the formulation of their dynamic carrier collaboration model in which a set of collaborative routes that minimize the total cost is identified. They also compare the collaboration with the short-term leasing and show that collaboration is always benefits. Dai and Chen (2012) propose a method based on Lagrangian relaxation to solve the collaborative transportation planning problem with multiple carriers in less than truckload transportation.

As we can see in table 1, papers dealing with collaborative transportation management consider mainly direct routing but do not consider consolidation hubs. Only Pan et al. (2010) consider consolidation hubs, but they don't consider routing. In this paper, we propose an approach based on Pan et al. (2010) but with consideration of routing.

3. PROBLEM STATEMENT

In the context of less than truckload transportation, suppliers can send half-filled trucks, and on the other side, customers can receive half-filled trucks. A solution to reduce the number of trucks used and so on, the total distance travelled and the total GHG emissions is to pool the different supply chains by selecting two kinds of hubs between the suppliers and the customers (Pan *et al.*, 2010). We also add the possibility for a truck to load at several suppliers and then deliver several customers (see Figure 1).
This problem results as the following mixed-integer linear model:

Notations:
Sets:

O	Set of suppliers
D	Set of customers
USH	Set of upstream hubs
DSH	Set of downstream hubs
V	Set of vehicles
K	Set of products

Constants:

C	Costs per km per vehicle
E_{min}	CO_2 Emissions per km per empty vehicle
E	CO_2 Emissions per km per quantity of product in a truck
Q	Vehicles capacity

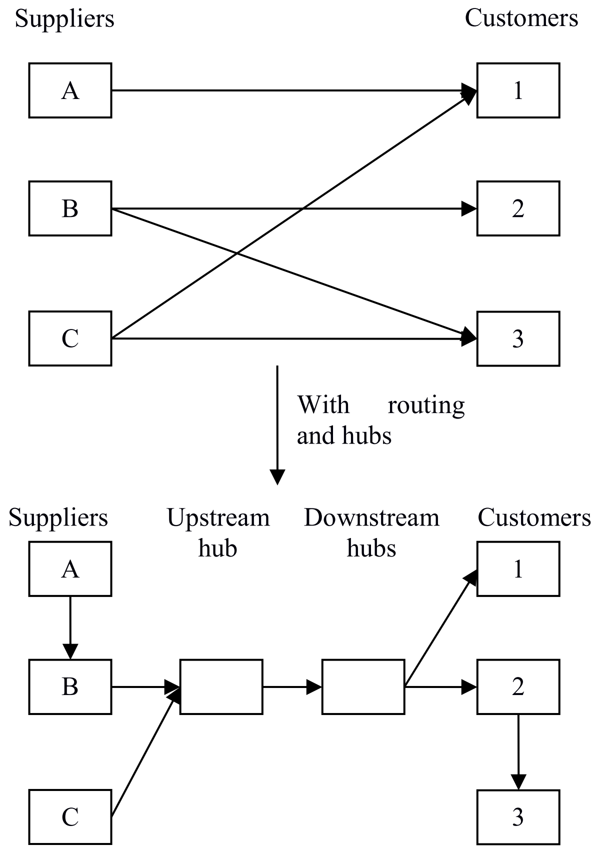

Figure 1 - Example of collaboration with routing and pooling

Parameters:
d_{ij} Distance between two nodes i and j
q_{ij}^{k} Quantity of product k to deliver between i and j
Variables:
x_{ij}^{v} 1 if vehicle v is on the flow ij, 0 if not
y_{ij}^{vk} Quantity of product k in the vehicle v between i and j

$$\begin{aligned} Min &\sum_{o\in O}\sum_{o'\in O}\sum_{v\in V}\left(E_{min} d_{oo'} x_{oo'}^{v} + \sum_{k\in K} E d_{oo'} y_{oo'}^{vk}\right) \\ &+ \sum_{o\in O}\sum_{m\in USH}\sum_{v\in V}\left(E_{min} d_{om} x_{om}^{v} + \sum_{k\in K} E d_{om} y_{om}^{vk}\right) \\ &+ \sum_{m\in USH}\sum_{n\in DSH}\sum_{v\in V}\left(E_{min} d_{mn} x_{mn}^{v} + \sum_{k\in K} E d_{mn} y_{mn}^{vk}\right) \\ &+ \sum_{n\in DSH}\sum_{d\in D}\sum_{v\in V}\left(E_{min} d_{nd} x_{nd}^{v} + \sum_{k\in K} E d_{nd} y_{nd}^{vk}\right) \\ &+ \sum_{d\in D}\sum_{d'\in D}\sum_{v\in V}\left(E_{min} d_{dd'} x_{dd'}^{v} + \sum_{k\in K} E d_{dd'} y_{dd'}^{vk}\right) \end{aligned} \quad (1)$$

st.

$$\sum_{v\in V}\left(\sum_{o'\in O} y_{oo'}^{vk} + \sum_{m\in USH} y_{om}^{vk} - \sum_{o'\in O} y_{o'o}^{vk}\right) = \sum_{d\in D} q_{od}^{k}, \quad \forall o\in O, \forall k\in K \quad (2)$$

$$\sum_{v\in V}\left(\sum_{n\in DSH} y_{nd}^{vk} + \sum_{d'\in D} y_{d'd}^{vk} - \sum_{d'\in D} y_{dd'}^{vk}\right) = \sum_{o\in O} q_{od}^{k}, \quad \forall d\in D, \forall k\in K \quad (3)$$

$$\sum_{o'\in O} y_{oo'}^{vk} + \sum_{m\in USH} y_{om}^{vk} \geq \sum_{o'\in O} y_{o'o}^{vk}, \forall o\in O, \forall v\in V, \forall k\in K \quad (4)$$

$$\sum_{n\in DSH} y_{nd}^{vk} + \sum_{d'\in D} y_{d'd}^{vk} \geq \sum_{d'\in D} y_{dd'}^{vk}, \forall d\in D, \forall v\in V, \forall k\in K \quad (5)$$

$$\sum_{o\in O}\sum_{v\in V} y_{om}^{vk} = \sum_{n\in DSH}\sum_{v\in V} y_{mn}^{vk}, \forall m\in USH, \forall k\in K \quad (6)$$

$$\sum_{m\in USH}\sum_{v\in V} y_{mn}^{vk} = \sum_{d\in D}\sum_{v\in V} y_{nd}^{vk}, \forall n\in DSH, \forall k\in K \quad (7)$$

$$\sum_{o\in O} x_{oo'}^{v} + \sum_{m\in USH} x_{om}^{v} \leq 1, \forall o\in O, \forall v\in V \quad (8)$$

$$\sum_{n\in DSH} x_{mn}^{v} \leq 1, \forall m\in USH, \forall v\in V \quad (9)$$

$$\sum_{d\in D} x_{nd}^{v} \leq 1, \forall n\in DSH, \forall v\in V \quad (10)$$

$$\sum_{d'\in D} x_{dd'}^{v} \leq 1, \forall d\in D, \forall v\in V \quad (11)$$

$$\sum_{o'\in O} x_{o'o}^{v} \leq 1, \forall o\in O, \forall v\in V \quad (12)$$

$$\sum_{o\in O} x_{om}^{v} \leq 1, \forall m\in USH, \forall v\in V \quad (13)$$

$$\sum_{m\in USH} x_{mn}^{v} \leq 1, \forall n\in DSH, \forall v\in V \quad (14)$$

$$\sum_{n\in DSH} x_{nd}^{v} + \sum_{d'\in D} x_{d'd}^{v} \leq 1, \forall d\in D, \forall v\in V \quad (15)$$

$$Q x_{oo'}^{v} \geq \sum_{k\in K} y_{oo'}^{vk}, \forall o\in O, \forall o'\in O, \forall v\in V \quad (16)$$

$$Qx_{om}^{v} \geq \sum_{k \in K} y_{om}^{vk}, \forall o \in O, \forall m \in USH, \forall v \in V \quad (17)$$

$$Qx_{mn}^{v} \geq \sum_{k \in K} y_{mn}^{vk}, \forall m \in USH, \forall n \in DSH, \forall v \in V \quad (18)$$

$$Qx_{nd}^{v} \geq \sum_{k \in K} y_{nd}^{vk}, \forall n \in DSH, \forall d \in D, \forall v \in V \quad (19)$$

$$Qx_{dd'}^{v} \geq \sum_{k \in K} y_{dd'}^{vk}, \forall d \in D, \forall d' \in D, \forall v \in V \quad (20)$$

$$\sum_{o \in O} \sum_{m \in USH} x_{om}^{v} \leq 1, \forall v \in V \quad (21)$$

$$\sum_{m \in USH} \sum_{n \in DSH} x_{mn}^{v} \leq 1, \forall v \in V \quad (22)$$

$$\sum_{n \in DSH} \sum_{d \in D} x_{nd}^{v} \leq 1, \forall v \in V \quad (23)$$

$$x_{ij}^{v} = \{0; 1\}, \ \forall i, j \in O \cup D \cup USH \cup DSH, \forall v \in V \quad (24)$$

$$y_{ij}^{vk} \geq 0, \ \forall i, j \in O \cup D \cup USH \cup DSH, \forall v \in V, \forall k \in K \quad (25)$$

The objective function (1) is to minimize the total emissions according to the number of trucks, the distance travelled and the quantity of loads in the trucks. The constraint (2) ensures that the quantity of product that a supplier has to supply is respected. In the same way, the constraint (3) ensures that the demand of a customer for a product is respected. The constraints (4) and (5) respect the flow conservation of the suppliers and the customers. When leaving a supplier, the quantity of products in the truck has to be upper or equal than before it arrived. On the other side, when leaving a customer, the quantity of product has to be less or equal than before it arrived. The constraints (6) and (7) ensure that the quantity of products leaving a hub is equal to the quantity of product entering the hub. The constraints (8) to (11) ensure that a vehicle do not split when leaving a site. In the same way, the constraints (12) to (15) ensure that a truck is coming from only one site when it arrives in another site. The constraints (16) to (20) are the vehicles capacity constraints. Finally the constraints (21) to (23) ensure that a truck pass by one upstream hub and one downstream hub max.

This model is very complex due to the three index of the variable x. We can reduce the number of variable by suppressing the index v and transform x into an integer variable representing the number of trucks on the flow ij. But the presence of this index v makes the model more accurate. For each truck we can know the quantity of each kind of product and the exact route of the truck and the products. Moreover, this index allows easily to put different parameters for each truck such as the capacity or the emissions.

4. CASE STUDY

The case study is about collaborative transportation between two agri-food companies (named here A and B) which are transformers. These companies are both based in UK and have customers across Europe. They sent their products separately to each of their customers (Figure 2) using direct flows, even when the trucks are not fully loaded. The goal of this case study is to reduce the transportation distance in kilometres and also decreasing CO_2 emissions caused by food distribution, after implementing collaborative distribution (Figure 3).

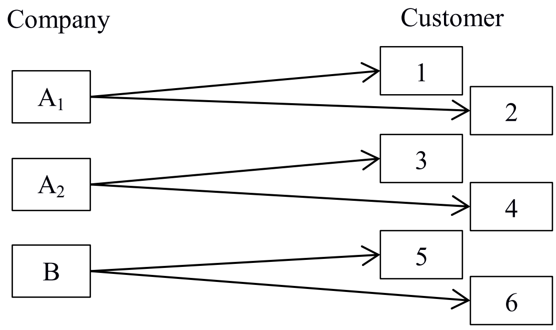

Figure 2 - The studied distribution network

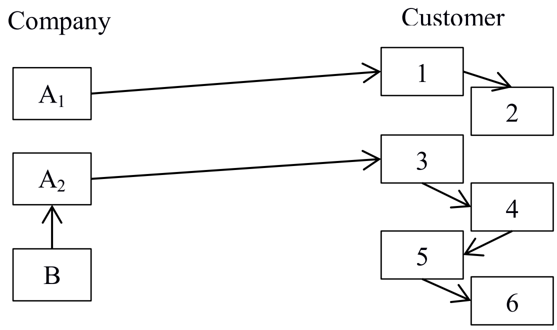

Figure 3 - Collaborative distribution by multi-loading multi-unloading

The studied companies have three production sites (two for the first one and one for the second one). They deliver 114 sites across the rest of Europe (mainly Netherlands, Belgium, Germany and France). Eight ports are identified to cross the sea; four in UK and four in Europe.

The demand of customers collected varies according the company and the horizon of time we consider is the period between December 2012 and May 2013. The data file contains:

- The name of the supplier,

- The collection date and the collection point,
- The delivery date, the delivery point,
- The number of pallets required per each customer.
- Real distances are provided, and travel time between each pair of sites as well (except for a few sites).
- The list of ports in England and the rest of Europe with the connections allowed between these ports are given.

In this study, suppliers can send, or customers can receive, half-filled trucks. In the model, to optimize the filling rate of trucks, one vehicle can pick up at several suppliers and can deliver several customers in one route. Moreover, for each truck, one port in England and one port in the rest of Europe are selected. We have to mention that here ports are not used as consolidation nodes but only as crossing points (that means that shipments are not reorganised in the ports). Indeed, as a characteristic of the case study, it is the same trucks that have to pick up at the suppliers and to deliver the final customers. Moreover, the ports do not have necessarily the capacity of doing consolidation. The goal is to reduce the CO_2 emissions. In order to focus on the benefits of the performed optimisation on term of additional aspects of sustainability, we calculate in our experimental study other metrics depending on the distance and given as costs according to (CE Delft, 2011). These metrics are namely water pollution cost, air pollution cost, accidents cost and noise cost.

We use the additional data in our model:

- We consider a capacity of 24 pallets for the trucks when there are only pallets from the first company in the truck.
- We consider a capacity of 22 pallets for the trucks when there is at least 1 pallet from the second company in the truck.
- For simplification, we consider that the weight of a pallet is one tonne (in fact that is true for the majority of the pallet).
- The emissions coefficient per kilometre for an empty truck taken into account is 0.772kg/km (Pan *et al.*, 2010).
- The emissions coefficient per kilometres per pallet added in a truck is 13.5g/km (Pan *et al.*, 2010).
- The transport cost used is 0.657€ per truck/km (www.cnr.fr).
- The water pollution cost used is 6.7€/1000tkm (CE Delft, 2011).
- The air pollution cost used is 0.8€/1000tkm (CE Delft, 2011).
- The accidents cost used is 10.2€/1000tkm (CE Delft, 2011).
- The noise cost used is 1.8€/1000tkm (CE Delft, 2011).

- We don't consider time windows for the delivery of goods.
- The distance used between two ports is Euclidian distance.
- In the as is scenario, ports are selected using the shortest path between collection and delivery nodes.
- For simplification, the emissions are calculated by the same way whatever a truck is on the road or on a boat.

The capacity of trucks is reduced here because of the configuration and the size of the products. Indeed the products are a little bit larger than the pallets so there is to be a space between two pallets. As the products of the second company are larger than the product of the first one, the capacity of a truck with products of the second company is smaller than capacity with only products of the first one. All the costs are given for information purposes only. Our goal is to minimize the total emissions.

We use the model presented above to solve this problem. As the ports here are not considered as consolidation nodes, we make some modifications to the model. We replace the constraints (6) and (7) by the following constraints (26) and (27):

$$\sum_{o \in O} y_{om}^{vk} = \sum_{n \in DSH} y_{mn}^{vk}, \forall m \in USH, \forall k \in K, \forall v \in V \quad (26)$$

$$\sum_{m \in USH} y_{mn}^{vk} = \sum_{d \in D} y_{nd}^{vk}, \forall n \in DSH, \forall k \in K, v \in V \quad (27)$$

With these constraints, the flow conservation in the hubs is respected for a given truck and not only for a given product.

5. RESULTS

The model is run for a one week horizon. All the deliveries are grouped by delivery date, from Monday to Saturday. An instance of week contains 3 suppliers, 4 upstream ports, 4 downstream ports and between 10 to 20 customers according to the week. To calculate the as is indicators, for each customer's demand, we calculate the minimum number of trucks required to fulfil the demand. Then we select the both ports that minimize distance between the supplier and the customer so we can calculate the emissions and the costs according to the number of trucks, the distance and the demand. Finally we add the results of all the orders of a week. After solving the model, routes are created to optimize the load of trucks for a specified week. The simulation is executed on six months: from December 2012 to May 2013. The model is solved with CPLEX 12.6 on a Quad core CPU (2.3GHz) and 6GB of RAM. As the problem is very complex to solve and cannot be resolve in a reasonable time, a time limit of 900 seconds is imposed.

The gap between the solution found and the lower bound varies between 2 and 5%. The table 2 shows the total results by month.

Period	3BL	Indicators	As is	To be	Improvement
Month1					
Dec 2012	Initial metrics	Emissions(Kg)	49590	44925	9.41%
		Nb Trucks	77	59	23.38%
		Distances (Km)	49052	42541	13.27%
		Time(h)	918	766	16.52%
	Economical	Transportation cost (€)	32227	27950	13.27%
	Environmental	Water pollution(€)	942	817	13.27%
		Air Pollution (€)	7888	6841	13.27%
	Social	Accidents (€)	12008	10414	13.27%
		Noise (€)	2119	1838	13.27%
Month2					
Jan 2013	Initial metrics	Emissions(Kg)	55125	46205	16.18%
		Nb Trucks	72	52	27.78%
		Distances (Km)	57051	44964	21.19%
		Time(h)	1018	795	21.97%
	Economical	Transportation cost (€)	37482	29541	21.19%
	Environmental	Water pollution(€)	1095	863	21.19%
		Air Pollution (€)	9174	7230	21.19%
	Social	Accidents (€)	13966	11007	21.19%
		Noise (€)	2465	1942	21.19%
Month3					
Feb 2013	Initial metrics	Emissions(Kg)	69375	59769	13.85%
		Nb Trucks	97	71	26.80%
		Distances (Km)	70278	57441	18.27%
		Time(h)	1264	994	21.35%
	Economical	Transportation cost (€)	46173	37739	18.27%
	Environmental	Water pollution(€)	1349	1103	18.27%
		Air Pollution (€)	11301	9237	18.27%
	Social	Accidents (€)	17204	14062	18.27%
		Noise (€)	3036	2481	18.27%
Month4					
Mar 2013	Initial metrics	Emissions(Kg)	59462	52756	11.28%
		Nb Trucks	78	59	24.36%
		Distances (Km)	60398	51281	15.09%
		Time(h)	1081	896	17.08%
	Economical	Transportation cost (€)	39681	33692	15.09%
	Environmental	Water pollution(€)	1160	985	15.09%
		Air Pollution (€)	9712	8246	15.09%
	Social	Accidents (€)	14785	12554	15.09%
		Noise (€)	2609	2215	15.09%
Month5					
Apr 2013	Initial metrics	Emissions(Kg)	74215	64416	13.20%

Period	3BL	Indicators	As is	To be	Improvement
		Nb Trucks	97	71	26.80%
		Distances (Km)	76163	63104	17.15%
		Time(h)	1347	1076	20.11%
	Economical	Transportation cost (€)	50039	41459	17.15%
	Environmental	Water pollution(€)	1462	1212	17.15%
		Air Pollution (€)	12247	10147	17.15%
	Social	Accidents (€)	18645	15448	17.15%
		Noise (€)	3290	2726	17.15%
Month6					
May 2013	Initial metrics	Emissions(Kg)	29178	23804	18.42%
		Nb Trucks	32	21	34.38%
		Distances (Km)	31073	23907	23.06%
		Time(h)	565	414	26.74%
	Economical	Transportation cost (€)	20415	15707	23.06%
	Environmental	Water pollution(€)	597	459	23.06%
		Air Pollution (€)	4997	3844	23.06%
	Social	Accidents (€)	7607	5852	23.06%
		Noise (€)	1342	1033	23.06%
Total					
	Initial metrics	Emissions(Kg)	336945	291876	13.38%
		Nb Trucks	453	333	26.49%
		Distances (Km)	344015	283239	17.67%
		Time(h)	6192	4941	20.21%
	Economical	Transportation cost (€)	226018	186088	17.67%
	Environmental	Water pollution(€)	6605	5438	17.67%
		Air Pollution (€)	55318	45545	17.67%
	Social	Accidents (€)	84215	69337	17.67%
		Noise (€)	14861	12236	17.67%

Table 2 - Values of different sustainable indicators without and with collaboration

We can see that collaborating by grouping loads can have benefits for the companies in term of transportation. Here, for the six months, the number of trucks used, the distance travelled, the emissions and the costs are reduced. Indeed, the total emissions for the six months are reduced by 13.38% and the total distance and costs are reduced by 17.67%. The distance reduction varies from 13.27% for the month 1 to 23.06% for the month 6. These differences in the results can be explained by the number of trucks already full in the as is case. More there are trucks with full load, less we can reduce the emissions and the costs.

6. CONCLUSIONS

The collaboration in supply chains is becoming more and more important for companies especially when it gives positive effects in the sustainability of the supply chain. In this paper, we presented a model associating the pooling of different supply chains by adding the two level hubs constraint in a vehicle routing problem among several companies to optimize the filling rates of the trucks. This results as the reduction of distance travelled and sustainable indicators such as costs, CO_2 emissions, pollution, accidents and noise.

Thanks to the companies, we could have tested the model on real data on six months. We were able to reduce the emissions by 13% and the costs by almost 18% in average. Hence, we arrive to show the role of collaborative distribution for developing the green supply chain management.

However, because of the characteristic of the case study, we don't consider consolidation here. So we cannot see what can be the benefits of consolidation in the collaboration of several companies. Moreover we don't consider time windows so we cannot study the impact of time (which is an important factor in agri-food business, especially with perishable food) on the results. Finally, due to the great complexity of the problem, the creation of heuristics or meta-heuristics can be a work to pursue.

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