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Ouhader H., El Kyal M. (2021) Sustainable Horizontal Collaboration: A Case Study in Moroccan Dry Foods Distribution. In: Camarinha-Matos L.M., Boucher X., Afsarmanesh H. (eds) Smart and Sustainable Collaborative Networks 4.0. PRO-VE 2021. IFIP Advances in Information and Communication Technology, vol 629. Springer, Cham. https://doi.org/10.1007/978-3-030-85969-5_73

Sustainable Horizontal Collaboration: A Case Study in Moroccan Dry Foods Distribution

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Abstract. The paper develops, for partners, a decision tool to assess the economic and ecological impact of collaborative freight delivery, before accepting to integrate a horizontal cooperative coalition. The proposed mechanism is based on the design of a sustainable collaborative supply chain for specific competing dry food distributors in Morocco. The success of such practice requires addressing different issues, among them: the redesign of the supply chain and the fair cost allocation to participating partners. An extension of the two echelons Location Routing Problem (2E-LRP) was exploited, to investigate how this collaboration can support the participants during a predefined planning horizon. The Shapley value method is used to evaluate the individual opportunities savings. We opt for Multi-objective to detect a good trade-off between the economic objective and the ecological one. Case study confirms the economic and environmental positive impact of the shippers' collaboration with different optimal network configurations.

Keywords: horizontal logistics collaboration; network design; two-echelon Location Routing problem; multi-objective optimization; sustainability, case study.

1 Background and Motivation of the Research

The multi-stakeholder partnerships and collaboration are crucial in efforts toward sustainable supply chain [1] . Logistic collaboration becomes an interesting topic and it receives considerable attention in recent years. (Cao & Zhang 2011) [2] define supply chain collaboration (SCC) as like «a partnership process where two or more autonomous firms work closely to plan and execute supply chain operations toward common goals and mutual benefits». Different types of classifications for SCC exist. The most expanded referring to its direction. SCC is classified into two categories: vertical and horizontal collaboration. The vertical collaboration concerns two or more organizations (receiver, shipper, carrier) , which share their responsibilities, resources, and data information to serve relatively similar end customers [3]. Horizontal collaboration occurs between companies in the same level of supply chain [4]. Vertical cooperation has been the focus of various research efforts over the last decades. Horizontal cooperation (HC) is starting to gain traction as a one of the key policies to assure sustainable supply chain ([5], [6]) .There are several ways for HC: carriers collaboration and shippers collaboration.

Over the last years, a good recent reviews on HC appeared in Logistic and Transportation as, [5], [7], [8] [9] and [10] . These reviews pointed out the scarcity of papers integrated the environmental issue in HC analysis. Compared to carriers' collaboration, there are few works on the problem of shippers' collaboration. From operation research approach, most of papers were based on vehicle routing problem and its variants whereas few papers treated supply chain design directly, where facility location or location routing decisions should be taken in collaboration with other supply chain partners. For interested readers, Prodhon & Prins 2014 [13] published exhaustive literature review of Location Routing problem (LRP).

A few studies have analyzed the benefits of HC by combining location and routing decisions such as [14], [15], [16] and [17] but they focused on economic indicators. Works as [18], [19]) and [20] quantified the environmental and economic effect of implementing HC but , optimized separately. To minimize costs and carbon emission under a bi-objective approach , (Yong et al. 2018) [21] studied variants of vehicle routing problem (VRP) without integrating facility location (FL) and (Mrabti et al. 2020) [22] suggested a FL model without integrating VRP. Recently , (Aloui et al. 2021) [12] proposed a bi-objective ILRP which combines routing, facility location and inventory decisions to assess the benefits of HC. This study has not been tested in real life-case. It was based on randomly instances and hypothetical data. Furthermore this study did not address the allocation of individual savings between partners.

For that, we note the need to gain a comprehensive perspective of the supply chain design and sustainability in horizontal collaboration between shippers through multi-objective decision-making models. These models permit to decision makers to understand the potentialities of such alliances.

In our previous works ([11] and [23]), we investigated the potential economic and ecological impacts of combining depot location and vehicle routing decisions in urban road freight transportation under HC. We proposed a multi-objective, two echelon location routing problem (2E-LRP) to evaluate, the tradeoff between the objectives. In these works, extended known instances representing the real distribution in urban area were used to test the proposed model.

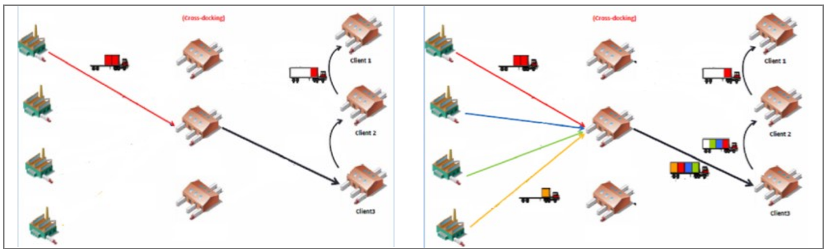
Due the importance of food wholesale supply chain, we evaluate in the current study, the impact of HC in this supply chain efficiency. We extend the 2E-LRP mathematical model developed in our previous studies to consider multi-period planning framework and we test the applicability of the model on a case of cooperative coalition composed of dry food wholesalers operating in Morocco.

The remainder of the article is structured as follows. In Section 2 we introduce the case study, in Section 3 we describe our optimization approach, in Section 4 we show and discuss the results, and in Section 5 we conclude this article and suggest future research directions.

2 Case Study Description

We evaluate, in this paper, the effect of implementing HC in distribution for a dry food supply chain in the Moroccan economic region of Souss-Massa. We consider a coalition of three independent dry foods distributors specializing in the wholesale distribution of flour products with more than 20 years of experience in the sector. The companies are designated as (BG, BL and BB) to maintain its anonymity. They service many different types of customers such as bakeries, grocery or retail stores and resellers. All partners compete with each other, but they have to look for new ways to be competitive. Actually, these distributors organize their logistics individually but aim to intensify partnership to reduce cost and emissions by joining their distribution decision. Goods are distributed to customers via transitional depots. Trucks are utilized to transport directly goods to these depots for consolidating flows. Later, goods are delivered to customers using small vehicles. Our study does not suppose inventory planning at depots (cross- docking facilities) (see Fig.1).

We redesign the distribution network to support horizontal collaboration with the objectives of minimizing, the transportation cost and carbon emissions in a two-echelon distribution system. The current problem combines two decisions: Location – allocation problem and routing problem.



Stand alone scenario	Collaborative scenario

Fig. 1. Stand alone scenario Vs Collaborative scenario

3 Modeling and Optimization Approach

The problem is modeled as bi-objective 2E-LRP extended from our previous work [11] , to consider multi-period planning. The problem consist of selecting a group of depots over the planning horizon, defining customers to visit for each period, allocating customers to chosen depots and assigning the routes serving the customers to each depot. The studied problem is defined on a directed, weighted graph and on a horizon H composed of P periods with shipping date t ∈ P. In order to convert the model to a multi-period model, the index t, which represents each period of the planning horizon, is included in the single period model equations.

We adopt the same assumptions and constraints as presented in [11].The economic objective function includes the fixed cost of exploiting depots, the handling cost in depots, the fixed costs of trucks and vehicles and the traversal costs of the arcs in the two distribution levels. The environmental objective consists of carbon emissions induced by the trucks and vehicles. These emissions depend on travelled distances, load and capacity of vehicles or trucks , confirmed to European studies such as [24], [25] and [26]. This ecological model is generally easy to apply in optimization problems. Due to space limitation, the rigorous mathematical description of the model is beyond the scope of this article and is detailed in [11].

The 2E-LRP models can be implemented to analyze the two scenarios: Non collaborative scenario (NCS) and the collaborative scenario (CS). Three base cases will be used for analysis: (i) Cost minimization (C_min) where the economic objective is solved (ii) Emissions minimization (Em_min) where environmental objective is solved (iii) Transportation cost minimization versus carbon emissions reduction (C_St_Em) where the bi-objective model is solved.

The model is implemented and solved exactly using commercial solver MATLAB 2014 (which uses a branch-and-bound algorithm) and tested on a 4.2 GHz Core i7 desktop with 16 GB RAM and a 64-bits operating system under Windows 10 environment desktop.

Because of confidentiality, no cost can be shown in this manuscript. Nevertheless, we evaluate the impact of HC based on the percentage of generated savings, comparing collaboration scenario with the stand alone one.

4 Results

4.1. Data andI

The studied product is the flour packaged in bags of 25Kg. Partners provided us with a record on four weeks orders placed by the customers. The weekly delivery is once and the average demand per customer is 11 units. Each supplier has its own and unshared customers with other partners. In collaboration, suppliers will share their own depots. Eight potential depot locations and 37 delivery points have been identified (See Table 1). The travel distances and the travel times were calculated using the Google Distance Matrix API which provides travel distance and time for a matrix of origins and destinations. We consider groups of homogeneous vehicles and trucks. Their characteristics are summarized in Table 2. According to the speed limitation and traffic condition, speeds are set as 60 km/h of trucks and as 30 km/h for urban vehicles. All customers must be served between 6am and 11pm. Then the urban routes cannot exceed a time length of 5 hours. Because of confidentiality, we cannot reveal the sensitive data and information (e.g. demands, geographic localization and costs). Further parameters are available on demand to the corresponding author of this paper.

Table 1. Partners' characteristics

Supplier	Depots	Customers' Number	% of the total delivered quantities of the coalition
BG	DC1, DC2 and DC6	14	40%
BL	DC3, DC4 and DC7	13	41%
BB	DC5 and DC8	10	19%

Table 2. Trucks and vehicles characteristic

	Urban vehicle	Truck
Type	RENAULT-Master FORGON TRACTION L2H3 2,8T (Base cases)	Volvo FL514 4x2 Platform 14 ton
Capacity (Bags)	55	150
$E_{(empty)}(g/CO)$	208	650
$E_{(full)}(g/CO)$	234	780

4.2. Single Objective Approach

In this part, we consider a single objective approach to evaluate the potential impacts of cooperatively reducing cost as well as emissions.

Non Collaborative Scenario (NCS). First, we evaluate the extreme solutions in the two cases (C_min) and (Em_min). Focusing on the aggregated amounts all over the planning horizon(Four weeks), results are presented in Table 3. The load rates are calculated as (total demand of route) / (capacity of the vehicle/truck) for each vehicle and truck. We calculate the trucks' and vehicles' numbers as the maximum number performed by vehicles or trucks during a period over the horizon planning. Results show that, for the three suppliers, lower environmental impact involves a higher transportation cost. For suppliers BG, BL and BB, carbon emission reduction with 18%, 14% and 38 % can be achieved, respectively, at 11%, 9.8% and 6.5% augmentation on the cost of the C_min case. From Table 3, this reduction is related to the decrease of travelled distances after the modification of chosen depots in Em_min case. These DCs are better propagated and closer to customers. These depots have more expensive open or handling costs, which justifies the increase of shipment cost. Compared with C_min case, the vehicle load factor (VLR) decrease in Em_min case as the number of vehicle increases and the number of customers allocated to depots is modified. The average load rates of truck (TLR) do not change because the number of trucks is the same in both cases.

Collaborative Scenario (CS). To assess the potential impacts of HC in the studied supply chain, the cooperative scenario is compared to the stand alone scenario. To evaluate the NCS, the sum of transportation cost, emissions and other metrics of individual companies is calculated. The obtained results are presented in the two last columns of Table 3 and in Fig.2. Results show that the collaborative scenario surpasses the non-collaborative one in all cases. Gaps between the two scenarios are positives, proving the profitability of horizontal collaboration. In C_min case, a profit of 9.40% and emissions reduction of 4.66% are obtained. In Em_min case, a profit of 5.58% and emissions reduction of 23.57% are obtained. As shown in Table.3 and fig.2, these positive gaps is related to the diminution of the travelled distances and the vehicles' number after the new assignment of customers to depots and the augmentation of vehicles' load rates . Also the number of selected depots decreases from 5 to 3 after collaboration, leading to the reduction of facility opening costs.

Table 3. Summary results for cooperative and non cooperative cases

	Scenario	(kgCO2)	Travelled distances (Km)	Trucks number	Vehicles number	satellites number : open satellites/ number of assigned customers	TLR %	VLR %
BG	C_min	392	560	3	5	2:DC2/9;DC1/5	65.4	87.2
	Em_min	324	452	3	6	2:DC2/10;DC6/4	65.4	72.6
BL	C_min	284	388	3	6	2:DC4/10;DC3/3	66	73.4
	Em_min	244	332	3	6	2:DC7/3;DC3/10	66	73.4
BB	C_min	96	188	1	3	1:DC5/10	96	71.2
	Em_min	60	92	1	3	1:DC8/10	96	71.2
Total NCS	C_min	772	1136	7	14	5:DC1/5;DC2/9; DC3/3;DC4/10; DC5/10	70	77.8
	Em_min	628	876	7	15	5:DC2/10;DC3/10; DC6/4;DC7/3; DC8/10	70	72.6
CS	C_min	736	960	7	12	3:DC2/10;DC4/11; DC5/16	70	90.74
	Em_min	480	664	7	13	3:DC2/4;DC3/24; DC8/9	70	83.76

Cost and emissions-sharing agreement . Before that the suppliers accept to participate in a HC coalition , an assessment of the individual opportunities savings must be available. Several cost allocation tools were suggested in the literature. (Guajardo 2016) [27] presented a review on cost allocation tools on collaborative transportation. The Shapley value method is quantified as a possible best practice by the industrials participating in European CO3-project ([28] and [29]). As explained by [30], the Shapley value is calculated using the marginal values of the each partner in all possible sub-coalitions and then the it incites partners to be collaborative as it guaranties the stability and fairness among partners. The cost allocated to partner p can be calculated by using (Equation 1). Given a player i, a coalition N, which consists of sub-coalitions S ⊆ N, that each generates a cost c(S), the Shapley value is:

$$C_i^{Shapley} = \sum_{S \subseteq N \setminus i} \frac{|S|!(n-|S|-1)!}{n!} * (c(S \cup i) - c(S))$$

$$C_i^{Shapley} = \sum_{S \subseteq N \setminus i} \frac{|S|!(n-|S|-1)!}{n!} * (c(S \cup i) - c(S$$

(1)

For these reason, we opt for the Shapley value method to allocate the collaborative gains in the current case study. Fig.3 focuses in the individual gains generated after collaboration. Results illustrate the economic and ecologic positive effect of the shippers' collaboration. While the Em_min case induces an average reduction in total cost in the range [4.81%, 8.38%], these values increases to [5.25%, 22.01%], when considering C_min case. For carbon emissions, gains increase from the range [0.64%, 13.53%] in C_min case to the range [16.97%, 28.52%] in Em_min case. This is due to the fact that minimizing costs requires opening less expensive depots which involve larger distances while minimizing emissions leads to shorter distances due to opening more expensive depots. The small supplier BB was the largest beneficiary of collaboration. This supplier obtained an economic profit of 22% in C_min case and an ecological gain of 13% in Em_min case. The big size suppliers have more customers and demand and then, more cost and emissions were allocated to these suppliers.

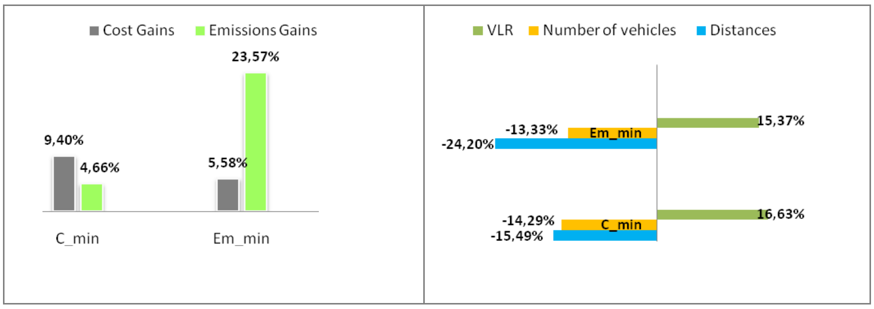


Fig.2. Aggregated gains analysis after collaboration

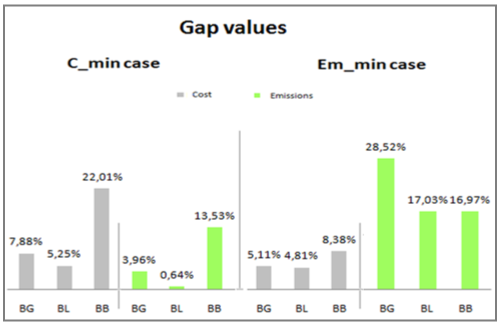


Fig.3. Gains analysis using Shapley value method in the two extreme cases

4.3. Trade-off Analysis

The Multi-objective analysis leads to detect a good trade-off between the economic objective and the ecological one. The efficient frontier is the group of non-dominated solutions for the association of different objectives [31]. We generate a set of efficient solutions using the approach adopted by [32] as a simple and easy technique to implement. The approach is based on the weighted sum method where a value of importance (α) is assigned to each objective, according to predefined interests of the decision [33]. As described by (Halevy et al. 2006) [32] , a normalization of the objectives is required because they have different units of measurement . Normalization utilizes the results of single objective approach. The objectives are aggregated into a single objective function .The function to optimize is as follows:

$$\text{Min } Z = \alpha \left(\frac{C - Cmin}{C\max - Cmin} \right) + (\alpha - 1)\left(\frac{E - Emin}{E\max - Emin} \right) \quad (2)$$

C is the function minimizing transportation Cost and ***E*** is the function minimizing transportation Emissions. The value α of ranges between 0 and 1.Values of *Cmin* and *Emax* were obtained by minimizing transportation cost (α =1). Minimizing transportation emissions allowed us to calculate *Cmax* and *Emin* were (α =0). The obtained Pareto frontiers is presented in Fig.4. Varying α 10 times leads to, only 5 different solutions. The case (α =0,2) is the most favorable scenario for ecological impact. The slopes of Pareto frontiers clearly decrease after this point.

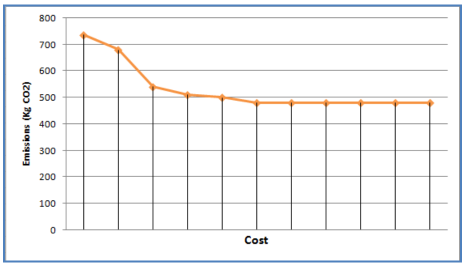


Fig.4. efficient frontier between the transportation cost and the ecological impact

5 Conclusion

Horizontal collaboration is one of the efficient strategies to persevere in the competitive market and to respond to the environmental concerns for wholesale supply chain. Found on multi-objective 2E-LRP, we confirmed the positive impact of horizontal collaboration on costs as well as on carbon emissions. We found that cost’s optimization and emissions’ optimization are two conflicting objectives. This brings to different optimal configurations of the studied network and leads to the dissimilar selection of depots and allocation of transport flows. Consequently, generated saving changed based on the selected configuration. These savings come from several factors. Collaboration contributed to the decrease of the number of open depots and travelled distances. Before any decision to integrate the coalition, each partner would like to quantify the impact of the collaboration on his own profit and loss. Therefore a fair allocation mechanism should be adopted. The allocation of cost and CO2 emissions is assured using the Shapley value method. The Multi-objective approach contributed to the detection of a good trade-off between the economic objective and the ecological one. Tests revealed that the incorporation of ecological condition into to economic objective influences the generated gains. The partners must decide on the solution based on their preferences and importance of cost and emissions gains. This research can be useful to other supply chain design problems in different areas as e-commerce, drug distribution or retail.

Important extensions to studied problem can be proposed like: The incorporation of additional objectives to optimize as individual preference. Here, each partner can precise, in priori, his preference regarding the reduction of logistical costs versus reduced CO2 emissions. To handle large-scale instances within reasonable computational times, the development of meta-heuristic approaches (such as NSGA-II) would be a meaningful direction.

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