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Sustainable supply chain design: A case of collaborative wholesale distribution

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ABSTRACT

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We assess the cooperative network design's efficiency outcomes in Morocco's food wholesale distribution. Before joining the collaborative coalition, we provide decision-makers with an initial preference instrument to assess the environmental and financial effects of cooperative freight distribution. We assess the practicality of incorporating decisions from the Facility Location Problem (FLP) and Vehicle Routing Problem (VRP) into partnerships for sustainable freight transportation. The coalition utilizes a 3PL provider's fleet of cars, therefore the Vehicles are exempt from having to go back to the consolidation depot; as a result, the fundamental issue becomes an open location routing problem (OLRP). Although there have been several studies on open location-routing problems, their application to horizontal shipper collaboration is new. For diverse collaboration scenarios, our computational approach is founded on two-echelon OLRP under a multiple objective and periods' framework. Every shipper involved in the partnership needs to receive gains. Therefore, evaluating the benefits to each individual shipper is essential for an effective and durable collaboration. This study addresses the issue of profit allocation to determine the collective and individual shipper's savings. By considering not just economic variables but also environmental factors, the Open LRP may help firms plan and optimize their collaborative supply chains in a more sustainable manner.

1. Introduction

Firms are investigating creative techniques to improve supply chain performance to tackle difficulties such as cost increases, growing client requirements, and growing urgency for balancing profitability with sustainability. A particular technique that is gaining momentum is supply chain horizontal collaboration. To attain common goals, horizontal collaboration requires the coordination and cooperation of firms that operate at the same level, including producers, retailers, distributors, and service providers. Horizontal collaboration offers the possibility to enhance productivity, decrease expenses, improve customer service, and develop sustainability by sharing resources, exchanging information, and collectively dealing with obstacles (Pan et al., 2019; Aloui et al., 2020; Expósito-izquierdo et al., 2022). Horizontal Logistics Collaboration (HLC) is fewer prevalent in both industry and in research than vertical collaboration, in which firms from various stage of the supply chain (distributors, retailers or manufacturers) collaborate (Defryn, 2017; Soysal et al., 2018; Gansterer & Hartl, 2018; Aloui et al., 2020). Previous HLC papers have focused on carrier collaboration instead of shipper collaboration. These factors lead to the study's focus on HLC between shippers. Design of a supply chain network SCND is a crucial component in collaborative supply chain efficiency. SCND is a complicated process that includes strategic decision-making to set up the optimal organization and functioning of a supply chain network. Despite that, very few articles addressed SCDN specifically, where collaboration with other stakeholders in the supply chain is necessary when addressing the facility location problem (FLP) and the vehicle routing problem (VRP). (Pan et al., 2019; Aloui et al., 2020; Expósitoizquierdo et al., 2022) .

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The Location Routing Problem (LRP) considers decisions on the vehicle routing and location of facilities. The standard LRP includes two components: (i) determining the ideal sites for facilities such as warehouses, or service centers to provide services to a particular group of clients. (ii) After selecting the facility locations, the challenge lies in determining the best routes for a group of vehicles to provide goods or services to clients. The goal is to reduce total expenses, which may include facility setting charges, transportation costs, and service charges. As separating the two decisions, VRP and FLP, may result in suboptimal solutions, the LRP applies an integrated solution technique. (Nagy & Salhi, 2007). A more extensive strategy to supply chain planning and optimization is made feasible by LRP, and this may offer companies several advantages such as cost reductions and improved efficiency (Drexl & Schneider, 2015). Consequently, integrated decision-making using LRP can greatly enhance the effectiveness of cooperative transportation networks. Certain firms are missing a private vehicle, or their existing fleet is insufficient to satisfy the needs of every client. In this situation, a third-party logistics (TPL) gets hired to handle all or some of the distribution operations. The TPL holds the delivery vehicles. Consequently, those vehicles get back to the TPL firm upon delivering its clients and not to the renting company's distribution facilities (Yu & Lin, 2015). In response to this issue, a novel LRP class referred to as Open Location routing problem (OLRP) has emerged. In the OLRP, once delivering the final consumer, the vehicles don't go back to their starting point, and an open route is formed (Hajghani et al., 2023). Both the first trip from the TPL company to the distribution center and the return trip from a final client to the TPL company are free of charge from the contractor's perspective. So, the only cost that the contractor worries about is the one-way trip from its depot to the final client. Since vehicles do not have to go back to an opening distribution center, the OLRP offers better route adaptability than the standard LRP. This makes it possible to plan routes more effectively and to decrease travel times or distances, which minimizes costs and boosts productivity. TPL service has become increasingly widespread across the globe; consequently, OLRP has grown in importance as a research problem for many firms. The OLRP has been given relatively less attention than the classic LRP.

Although cooperative shipping and location-routing are becoming progressively more common, researchers haven't considered how both may be coupled in horizontal shipper collaboration. Nevertheless, there are an increasing number of research on OLRP, its application to horizontal shipper collaboration is relatively recent. Based on a mathematical perspective, single objective approaches addressing economic issues served as the foundation for the optimization of cooperative supply chains, and sustainability integration has not received enough attention. As far as we know, a lack of study has been conducted on the shippers' collaborative OLRP considering sustainability concerns. To address this disparity, we investigate a practical OLRP for a horizontal cooperative coalition in this work.

As the main user of materials and energy, the food industry plays a significant part in raising Greenhouse gas emissions (GHG) emissions and wasting resources. Sustainability is a crucial concern in food supply chains because resources are limited and the need for food rises (Manteghi et al., 2021). In this context, we evaluate the efficiency of collaborative network building in food retailing in Morocco. Before joining this coalition, we propose to stakeholders an initial decision-making tool to evaluate the ecological and financial impacts of a cooperative freight distribution. We assess the possibilities of involving (FLP) and (VRP) issues in cooperative projects for environmentally conscious freight transportation. For the Supply Chain to operate as efficiently as possible overall, this combination is crucial. Using a TPL provider's service, the alliance avoids having the vehicles return to the depot, which makes the main problem an OLRP. The basis of our mathematical simulation is a multi-objective, two-echelon open location routing problem (2E-OLRP) for various cooperative situations with a multi-period perspective. Every shipper who takes part in the partnership must be profitable. Therefore, an efficient and durable collaboration depends on evaluating the benefits to each individual shipper. The gain allocation problem is established by this study. One of the key components that must be considered when building supply chain horizontal collaboration is the creation of cooperative alliances. Compatible collaborators are selected based on their shared objectives and matching competencies. To help companies make better choices and develop collaborative relationships, we investigate the suitability of the partners involved in the analyzed alliance. The purpose of this research is to broaden our understanding on cooperative supply chain design, rather than furthering the generation of LRP solution techniques. Given this information, we tackle the following research questions:

1. How does supply chain design affect the sustainability performance of a coalition under horizontal collaboration?
2. How do financial factors impact the environmental aspects?
3. How do environmental aspects impact the financial aspects?
4. How to identify suitable partners?
5. How to allocate costs and profits?

The other components of the article are arranged as follows: In the Section that follows, we highlight the relevant research in collaborative SCND and sustainability. Subsequently, our developed mathematical model and the case study are explained. Following that, the computational findings are highlighted and discussed. Lastly, we conclude and provide suggestions for further study.

2. Literature Review

First, we review research on the topics of Sustainability, Supply Chain Collaboration and supply chain planning and design under horizontal collaboration. Then, we focus on the papers that have considered collaborative LRP between shippers.

2.1. Sustainable supply chain

Sustainability is a result of creating a balance between economic growth, protecting the environment, and social responsibility (Tavakkoli et al., 2018). The term "triple-bottom line" (TBL) refers to the combination of these three dimensions and was first used by) (Elkington, 1997). Companies are fundamental contributors to sustainable development and their decisions at supply chain design and management are of great importance (Varsei & Polyakovskiy, 2015). Derived from the triple-bottom line perspective, (Seuring & Muller, 2008) outline that the sustainable supply chain management (SSCM) as "*the management of material and information flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social, and stakeholder requirements into account*". Based on this foundation, supply chain supply chain management (SSCM) focuses primarily on the forward supply chain and is enhanced by closed-loop SCM, which includes reverse logistics, recycling, and recuperation of goods (Brandenburg et al., 2014). Various terminologies have been employed to convey the intricate combination of sustainability and supply chain management. The terminology that most clearly highlights the close connections between sustainability and supply chain management are green supply chain management (GSCM) and sustainable supply chain management (SSCM), both of which are rapidly gaining in popularity (Ahi & Searcy, 2015). A supply chain may be forced to adopt sustainable practices due to several factors, including legislation and policy, community concerns, science and technology, the creation of goods, procurement, and operations (Hassini et al., 2012).

There are numerous approaches for evaluating GSCM and SSCM since there is disagreement about their definitions. In the scientific literature on SSCM and GSCM, Ahi and Searcy (2015b) investigated the evaluation techniques that have been presented. There is disagreement over the most suitable method to measure performance in these areas, as evidenced by the fact that most of the 2555 measures that were found were only used once. Air pollutants, Quality, energy use, greenhouse gas emissions and energy consumption were the five criteria that were utilized multiple times. According to the research, environmental issues were particularly observed. Among the most utilized economic indicators were return on investment and operational cost. Common considered social indicators included safety incidents, regulations, and public services. In the past ten years, several excellent survey articles have been released that explore and recommend future areas for research while emphasizing the significant contribution of quantitative models to sustainable supply chain management. Research on forward sustainable supply chain management that incorporated quantitative modeling techniques was reviewed by Seuring (2013). The study distinguished four common modeling strategies: (1) multi-criteria decision making (MCDM), (1) life-cycle assessment (LCA) based models, (3) analytical hierarchy process (AHP), (4) equilibrium models. In contrast to the environmental aspect, which was mainly addressed through expanding life-cycle assessment-based models, the authors emphasized the predominance of economic dimension analysis and a scarcity of research on the social part of sustainability.

To define the variables that are considered in the quantitative SSCM models that are currently in use as well as their limitations, (Brandenburg et al., 2014) concentrated on quantitative models for forward SSCM. The above survey revealed that, whereas transporters and retailers are rarely assessed, industrial firms predominate as the main analyzing actors in SSCM. Additionally, the most widely used SSCM models are normative models (prescriptive, problem-solving oriented), that primarily utilize linear programming/mixed integer linear programming (LP/MILP) and analytic hierarchy process/analytic network process (AHP/ANP) as solution methodologies. The authors suggested that there be increased focus on the investigation of sustainability in the areas of environmental risk management, warehousing, and transportation.

The literature that Eskandarpour et al. (2015) examined concentrated on optimization techniques and methods for Supply Chain Network Design (SCND) issues that explicitly evaluated at least two of the three aspects of sustainable development. The results demonstrated that while many works concentrate on environmental and economic issues, the social issues of sustainable development are less considered in quantitative studies when compared to environmental dimension, and even fewer studies cover all three dimensions simultaneously. According to (Eskandarpour et al., 2015), research on modeling approaches focuses on formulating deterministic Mixed-Integer Linear Programming (MILP) models that can be resolved via common modeling tools and solvers. In academic literature, the most common practical applications of sustainable SCND were in the manufacturing and waste management issues. The same authors proposed several study directions, including minimizing the general ecological impact through incorporating the supply chain network's greenhouse gas emissions into account in addition to other factors like waste generation or energy use; to further incorporate social factors into generic models adopting a multi-objective method, and to generate heuristic or more exact solutions of addressing SCND problem.

Recently, Seuring et al. (2022) highlighted the need for careful planning and reflection in SSCM research to address environmental and social issues, such as climate change. In the research, a supply chain management (SSCM) framework with nine conceptual components—such as cooperation and communication—was developed. This may open new opportunities for fostering innovation and enhancing supply networks' sustainability performance.

2.2. Collaborative supply chain

Firms may tackle the topic of sustainability in a variety of ways. Adopting management techniques can involve addressing supply chain challenges as well as fostering sustainability by concentrating on a company's resources and expertise (Correia et al., 2017). Additionally, to maintain competitiveness in the uncertain market, Small and Medium-Sized Enterprises (SME) look for innovative organizational and business models (Ben Salah et al., 2018). According to Ayala-orozco et al. (2018), multi-stakeholder alliances and cooperation are essential to activities aimed at creating sustainable supply chains. These factors make collaboration an interesting subject and in recent years, it has attracted more attention.

Audy et al. (2010) defined the collaboration as "*it occurs when two or more autonomous and self-interested business units form a coalition and exchange or share resources (including information) with the goal of making decisions or undertaking activities that will generate benefits that they cannot (or only partially) generate individually. The level of collaboration can range from information exchange, joint planning, joint execution, to strategic alliance*". According to Ben Salah et al. (2018), collaboration is the ultimate level of cooperation, involving the sharing of resources, risks, information, gains, and losses.

Supply chain collaboration (SCC) is one of the many different networks of cooperation that have emerged in recent years due to difficulties faced by companies and scientific fields. To maintain the efficacy as well as agility of their supply chain, companies look for possibilities to cooperate with partners beyond their own perimeters. Supply chain collaboration has been defined by several authors in different manners. (Hudnurkar et al., 2014) have made a census of different available definitions of the concept. Two principal definitions that were extensively adopted by most researchers. First Simatupang and Sridharan (2002) define SCC as like "*two or more independent companies [who] work jointly and execute supply chain operations with greater success than when acting in isolation*". Second, (Cao & Zhang, 2011) describes 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*». According to (Erhun & Keskinocak, 2011), cooperative efforts including design, planning and logistics offer a great deal of potential to enhance supply chains' performance. Out of all the approaches, collaborative logistics has attracted attention in the past few years to address the inefficiencies in freight transportation (Amer & Eltawil, 2015).

There are multiple SCC categories available. the most widespread in terms of orientation. Three categories constitute SCC: lateral, horizontal, and vertical collaboration. Vertical collaboration refers to the coordination and cooperation of various supply chain levels. Working together and collaborating between entities which are involved in the supply chain at the same level or stage is referred to as horizontal logistics collaboration. By pooling and combining resources both horizontally and vertically, Lateral Collaboration seeks to increase flexibility (Okdinawati & Simatupang, 2015). With numerous research papers published over the past few years, supply chain management has given more importance to CSC. The results of the systematic literature review conducted by (Chen et al., 2017) and (Janjevic et al., 2018), show that there is a growing interest in academic research about supply chain cooperation for sustainability. The research continues to be centered on economic and environmental factors, despite social issues receiving little attention. In addition, vertical collaboration has been the primary collaboration partner under investigation, but there hasn't been much focus on horizontal collaboration. According to (Cruijssen et al., 2023), there has been a noticeable increase in the number of articles about horizontal collaboration as a strategy to boost productivity and lower carbon emissions since 2020. We recognize that developing an extensive knowledge of sustainability through horizontal collaboration is necessary.

(Janjevic et al., 2018) classified horizontal cooperation into two categories according to the actors involved. Cooperation between shippers aims to reduce shipping costs by making better use of their fleet. Cooperation between a logistics service provider and carriers can accelerate delivery or save operating expenses. Because of their specific roles and incentives, they are often examined for independence (Chabot et al., 2018). While shipper collaboration has received less attention, carrier corporations have received more attention in the literature. For this reason, we concentrate on the shipper's cooperation while addressing distribution planning issues.

2.3.Supply chain planning and design under horizontal collaboration

One of the critical decisions impacting collaborative SSCM performance is distribution design. Bloemhof-ruwaard (2016) classified this issue into two major subjects: transportation and facility selection. Issues about location, dimension, and the number of facilities have considerable effects on supply chain efficiency. This is a problem of Logistics network design. This problem combines two decision-making stages. The decision of which locations to add to the network and the associated cost are the main topics of selecting level. We talk about facility location problems (FLP). The operational level assesses how a design will be exploited to meet the related demand. The decisions taken during transportation include the mode of transportation, the types and dimensions of the vehicle and the charge and routing of the vehicle. We address vehicle routing problems (VRP) (Bloemhof-ruwaard, 2016).

The Facility Location Problem (FLP) and the Vehicle Routing Problem (VRP) are combined to form the Location Routing Problem (LRP) which involves: (i) determining the ideal sites for facilities such as warehouses, or service centers to provide services to a particular group of clients, (ii) After selecting the facility locations, the challenge lies in determining the best routes for a group of vehicles to provide goods or services to clients. The LRP is an effective tool for improving transportation and logistics networks is the Location Routing Problem. It has several applications, and its advantages can greatly increase the efficiency and profitability of an organization (Prodhon & Prins, 2014),(Drexl & Schneider, 2015b). For interested readers, a recent review of (LRP) and its derivatives throughout the preceding ten years was published by (Mara et al., 2021). The primary principle behind cooperative logistics networks is consolidation. Different logistical infrastructures can be utilized as the distribution center (DC) for this consolidation. Several distribution strategies can be developed from those facilities. There are two main categories for them: Single echelon systems originate from direct client delivery from the DCs. By combining freight delivered by loaded trucks to cross-docking platforms known as satellites and small vehicles serving consumers from these satellites, two echelon systems (Fig. 1) seek to better optimize flows (Mancini et al., 2014). Crossdocking, as compared to usual warehousing, seeks to reduce the amount of time that goods remain in the warehouse. Ideally, products should not be kept for long, if at all. Rather, they are rapidly transported to outgoing vehicles. In today's dynamic and competitive business environment, the Two Echelon Logistics Distribution System is essential to optimizing an organization's distribution processes. Shipments can be combined and distributed regionally, reducing long-haul transportation, and optimizing delivery routes, thanks to DCs situated in strategically placed geographic areas. Through applying this strategy, lead times and transportation costs are reduced allowing companies to satisfy customer demands for rapid and effective delivery. The integration of Horizontal cooperation with the Two Echelon Logistics Distribution System generates numerous benefits for enterprises due to the ability to leverage shared resources, optimize distribution processes, and enhance supply chain performance.

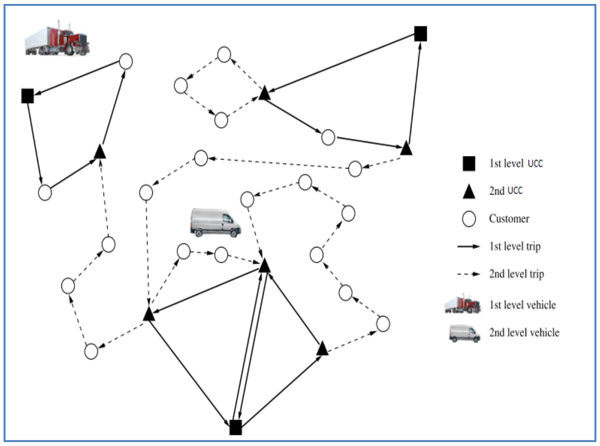


Fig. 1. Two-level distribution system (Adapted from (Cattaruzza et al., 2015))

Cooperative transportation planning has been the subject of several research studies published in recent decades which are applicable to various contexts and have distinct goals. Few research has specifically examined collaborative supply chain design, which focuses on the importance of decision-making with other supply chain partners on facility location routing problems (LRP). Vehicle routing problems (VRP) where the facility location (FLP) was taken in a previous step and cannot be modified, have drawn more focus from researchers (Ouhader & EL kyal, 2023). Readers with an interest in transportation collaborative vehicle routing problems are directed to the survey article(Gansterer & Hartl, 2020) . Although cooperative shipping and location-routing are becoming increasingly common, researchers haven't given much consideration to how both ideas may be combined in horizontal shipper collaboration (Ouhader & Kyal, 2017; Aloui, Mrabti, Hamani, & Delahoche, 2021; Osicka et al., 2018). A comparison of Latest publications on the LRP in horizontal shipper collaboration is shown in Table 1. The works of (Quintero-Araujo et al., 2017; Nataraj et al., 2019; Xu et al., 2018; Mrabti et al., 2020) and Aloui et al. (2021) adopted a single objective approach to assess the performance of the collaborative schemes. Aloui et al. (2021), Nataraj et al. (2019) and Quintero-Araujo et al. (2017) proposed an Inventory Location Routing Problem (ILRP) to evaluates the financial and ecological impacts of HLC by combining decisions about routing, facility location, and inventory. Xu et al. (2018) concentrated on evaluating a pooled distribution network's economic performance. On the other hand, Mrabti et al. (2020) concentrated on a pooled distribution network's ecological performance. There is a lack of Mult-objective research on the cooperative location routing challenge experienced by shippers. Few publications offer relevant research on this subject. The research of (Ouhader & Kyal, 2017; Ouhader & El kyal, 2017; Ouhader & El kyal, 2018; Ouhader & El kyal, 2020) explored a multi-objective 2E-LRP model utilizing LRP instances that replicated actual urban distribution networks, concentrating on emissions and distribution costs during a single period. Existing research rarely addressed collaboration over different periods in optimization models. However, a small number of studies addressed multi-objective optimization models under different periods, offering a potential avenue for further exploration. In (Ouhader & El kyal, 2021) the authors examine the compromise between the collaborative environmental and economic efficiencies across a set planning horizon using the weighted balanced sum. Aloui et al. (2021) and Aloui et al. (2022) developed a multi-objective mathematical model to optimize the accident rate, pollution, and logistical costs across multiple time periods. Recently, Ouhader and EL kyal (2023) used a multi-objective approach to model a two-echelon location routing problem, focusing on trade-offs between economic and ecological impacts. While participant benefit analysis is recognized as key to successful collaboration, the majority of existing research fails to address the crucial challenge of cost and profit allocation, hindering the development of equitable and efficient collaborative models**.** Except for the previously mentioned of Ouhader and El kyal, the only other research that examined the beneficial effects of collaboration were Mrabti et al. (2020) and Aloui, Mrabti, Hamani, Delahoche, et al. (2021). These studies combined LRP with the distribution of generated gains among the collaborators.

Table 1

Location routing problem in horizontal collaboration between shippers

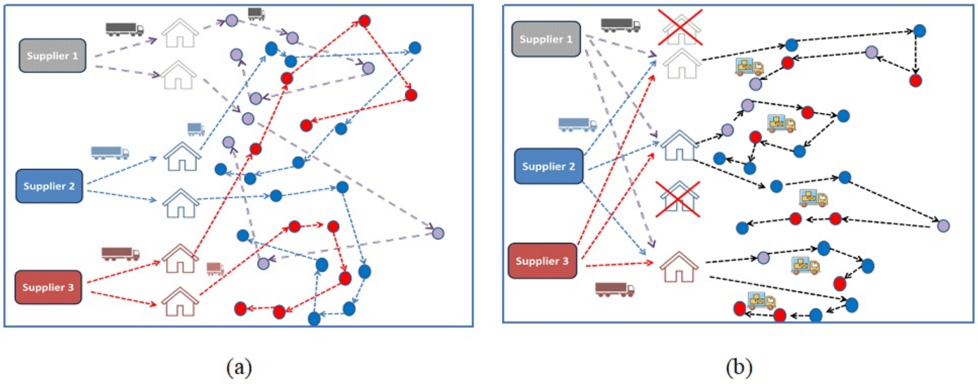
Authors	Classical LRP	Open LRP	Cross-docking	Economic concern	Environmental concern	Multi-Echelon	Multi-period	Multi-objective approach	Practical application	Profits allocation
(Ouhader & Kyal, 2017)	√		√	√	√	√		√		√
(Quintero-araujo et al., 2017)	√		√	√	√	-			_	-
(Ouhader & El kyal, 2017)	√		√	√	√	√		√		√
(Xu et al., 2018)	√		√	√					_	-
(Ouhader & El kyal, 2018)	√		√	√	√	√		√		√
(Nataraj et al., 2019)	√		√	√	√	-			_	-
(Ouhader & El kyal, 2020)	√		√	√	√	√		√		√
(Mrabti et al., 2020)	√				√	√			√	√
(Aloui, Hamani, & Delahoche, 2021)	√			√	√	√	√	√	√	-
(Aloui et al., 2021)	√			√	√	√	√		√	√
(Aloui et al., 2022)	√			√	√	√	√	√	-	-
(Ouhader & EL kyal, 2023)	√		√	√	√	√	√	√	√	√
This work	√	√	√	√	√		√	√	√	√

2.4. Objectives of the study

This review shows that although research on horizontal supply chain collaboration for sustainability has been more prominent in recent years, it is still in its early phases. It appears that little work has been carried out on multi-objective optimization for the design of collaboration planning between shippers across multiple time periods. Furthermore, there are few studies assessing the profits and cost allocation for the same problem. Most research focuses on VRP issues while few studies specifically address location routing issues (LRP), which should be solved jointly with other partners, in the context of collaborative supply chain design. The open location routing problem (OLRP) has been already discussed in traditional logistics however, no works have focused on two echelon OLRP in horizontal collaboration between shippers. This work addresses this research gap by investigating an open collaborative location routing problem under a multi-period model. Our approach prioritizes the economic and ecological impacts of horizontal cooperation between distributors. Our objective is to determine how the OLRP outperforms the collaborative network in terms of economic and ecological benefits. We also are interested in clearing up the issue of profits and cost allocation. The main contributions of the study are: (1) We introduce a sustainable open two echelon location routing problem in wholesale distribution. Different collaborative scenarios are proposed. (2) We propose models for multi-objective mixed-integer linear programming (MILP) with consideration for logistical costs and CO2 emissions. (3) A thorough evaluation and a case study on wholesale distribution are conducted to highlight the advantages of cooperation and offer managerial perspectives for decision-making. Computational tests are carried out to evaluate the strategies' sustained performance. (4) The gain allocation problem is established by this study. Compatible participants are chosen based on their shared objectives and matching competencies. we investigate the suitability of the partners involved in the analyzed alliance.

3. Materials and Methods

A real-world case study for distribution of a dry food in Morocco is taken into consideration for the suggested model's validation. We take into consideration an alliance of three distinct dry food distributors. The companies have been labeled as BB, BG, and BL to preserve their confidentiality. To pool resources and use their combined negotiating power to obtain lower rates for the products or services they buy, BG and BL have already joined together to form a purchasing group. These Partners must constantly seek out innovative methods to remain competitive despite their mutual competition. Although these distributors handle their logistics independently, they want to strengthen their collaboration to save transportation expenses and greenhouse gases by consolidating shipping and incorporating more collaborators such as BB. Cross-docking platforms are used to transfer goods to clients. Goods are transported directly to these platforms by trucks to consolidate flows (first echelon). Afterwards, small cars are used to deliver products to clients. A third-party logistics (TPL) has been hired to handle the distribution operations. Subsequently, routes are open in the second echelon, starting from a certain depot, serving a part of the customer, vehicles do not go back to the departure depot (Fig. 2). In a two-levels distribution system, we remodel the distribution network to facilitate horizontal cooperation while reducing transportation costs and carbon emissions. A bi-objective mixed-integer programming mathematical model is developed for the 2E-OLRP. The challenge consists of allocating every manufacturer and last client to an available depot, as well as addressing the resulting routing problem.



(a) (b)

Fig. 2. Cooperative and non-cooperative scenarios: (a) Non cooperative scenario; (b) Cooperative scenario

N clients, *D* depots, and *S* suppliers constitute the network. The problem is modeled on a horizon, *M* formed up of *P* periods with shipment times $\pi \in$ P. The fleet of trucks and vehicle that we use is homogeneous. The following assumptions inform the model's design:

- The proposed model is multi period.
- Each customer demand is deterministic and known during each shipping time
- Each depot can be served by different suppliers and several trucks during each shipping time.
- The number of vehicles and trucks is limited.
- No truck or vehicle is loaded over its maximum capacity.
- The production capacity of each supplier and the storage capacity of each depot are limited but can meet the entire demand.
- For the planning horizon, a single depot is assigned to each customer.
- At every shipment time, a single route must perform every consumer at the second level.
- Inter-satellite connections are prohibited.
- At each shipment time, every route in the second echelon should begin at the depot and finish at a specific customer.
- The vehicle's speed remains constant at the same level.

3.1. Indices, parameters, and Decision variables

The indices, parameters, and Decision variables are presented below:

Sets and Indices

S set of suppliers or distributors
W set of depots or warehouse
N set of costumers
Π set of time periods
t: index of period / $t \in \Pi$
k: index for nodes corresponding to suppliers / $k \in S$
i, j, l : index for the nodes corresponding to second echelon / $i,j,l \in W \cup N$

Parameters

$d_{(jkt)}$	*Request of client $j \in N$ from distributor $k \in S$ for each delivery time t*
CAS_k	*size of supplier $k \in S$*
CAW_w	*size of warehouse $w \in W$*
CT	*size of truck (first Echelon)*
CV	*size of vehicule (Second Echelon)*
$FCT_{\square}$	*Fixed costs of of using truck in the first echelon*
$FCV_{\square}$	*Fixed costs of using vehicule in second echelon*
FCD_w	*Fixed cost of establishing the warehouse w*
TRC_w	*Unit fulfilment cost of freight in warehouse w*
$C_{(kw)}$	*Truck travelling cost from supplier k to depot w*
$C_{(ij)}$	*Vehicle travelling cos from i to $j/i, j \in W \cup N$*
$DIS_{(ij)}$	*Distance from i to $j\ /i, j \in (S \cup W \cup N)$*
$TT_{(ij)}$	*Travel time from i to $j\ /i, j \in W \cup N$*
$CoE_{(T\_empty)}$	*CO2 gas emission coefficient of an vacant truck in the first echelon*
$CoE_{(T\_full)}$	*CO2 gas emission coefficient of loaded truckload of the first echelon*
$CoE_{(V\_empty)}$	*CO2 gas emission coefficient of vacant vehicle in second echelon*
$CoE_{(V\_full)}$	*CO2 gas emission coefficient of loaded truckload of a vehicle in second echelon*

- ***Decision variables***

$Q_{(kwt)}$	*Amount of the goods received from supplier k to warehouse w in each delivery time t*
$TN_{(kwt)}$	*The total count of trucks transferred from supplier k to warehouse w in each delivery time t*
$VN_{(wt)}$	*The total count of vehicles allocated to the located warehouse w in each delivery time t*
z_w	$\left\{\begin{matrix} 1 & \text{if } warehouse\ w \text{ is } located \\ 0 & otherwise \end{matrix}\right\}$
α_{jw}	$\left\{\begin{matrix} 1 & \text{if } customer \text{ j is } allocated \text{ to depot } w \\ 0 & otherwise \end{matrix}\right\}$
x_{ijt}	$\left\{\begin{matrix} 1 & \text{if vehicle travel from i to j in the second echelon the in delivery time t} \\ 0 & \text{otherwise} \end{matrix}\right\}$ $/\, i \in W \cup N, j \in N$
U_{kijt}	*Filled good k in a vehicle traveling from i to j in the second echelon the delivery time t t/i $\in W \cup N, j \in N; k \in S$*

3.2. Objective functions

- ***Economic objective***

The cost function (Eq. (1)) consists of: fixed cost of establishing depots, transshipment charges in depots, fixed cost of using the trucks in the first echelon, fixed cost of using vehicles in second echelon, traveling cost in the first echelon and traveling cost in the second echelon.

$$\min F1 = \sum_{w\in W} FCD_w \times z_w + \sum_{t\in\Pi}\sum_{k\in S}\sum_{w\in W} TRC_w \times Q_{(kwt)} + \sum_{t\in\Pi}\sum_{k\in S}\sum_{w\in W} FCT \times TN_{(kwt)} + \sum_{t\in\Pi}\sum_{w\in W} FCV \times VN_{\underset{\square}{wt}} + \sum_{t\in\Pi}\sum_{k\in S}\sum_{w\in W} TN_{(kwt)} \times C_{(kw)} + \sum_{t\in\Pi}\sum_{i\in W\cup N}\sum_{j\in N} C_{ij} \times x_{ijt} \tag{1}$$

- ***Ecological objective***

One of the most often used ecological criteria in the literature is greenhouse gas emissions. Compared to other criteria, GHG emissions offer a more concrete and more quantifiable standard (Manteghi et al., 2021). In this study, we measure CO2 emissions using the MEET which accounts for vehicle cargo. This method is frequently utilized in collaborative transport scenarios because of its easy nature (Pan et al., 2013; Hacardiaux & Tancrez, 2019; Aloui et al., 2022). As explained by Pan et al. (2013), the CO2 emissions function is:

$$\varepsilon\left(d_{ij}, c_k, x_{ij}^k\right) = \sum_k \sum_i \sum_j d_{ij} \times \left[\left(E_{(full)} - E_{(empty)}\right) \times \frac{x_{ij}^k}{c_k} + E_{(empty)} \times \left\lceil \frac{x_{ij}^k}{c_k} \right\rceil\right] \tag{2}$$

ε (d, c, x) is the vehicle generated emissions. The quantity of product on vehicle's type k on the arcs (i, j) is presented by x_{ij}^{k}. The emissions of a full and empty vehicle are respectively presented by $E_{(full)}$ and $E_{(empty)}$. C_k is the truck payload and the distance between nodes i and j is d_{ij}. The term $\left\lceil \frac{x_{ij}^{k}}{c_k} \right\rceil$ denotes the closest higher integer to $\frac{x_{ij}^{k}}{c_k}$. Based on this formula, we developed the Emission function:

$$\begin{aligned} \boldsymbol{min\ F2} = \sum_{t\in\Pi}\sum_{k\in S}\sum_{w\in W} d_{kw} \times \left[\left[\left(CoE_{(T_{full})} - CoE_{(T_{empty})}\right) \times \frac{Q_{(kwt)}}{CT}\right] + \left[CoE_{(T_{empty})} \times TN_{(kwt)}\right]\right] \\ + \sum_{t\in\Pi}\sum_{w\in W}\sum_{k\in S}\sum_{i\in W\cup N}\sum_{j\in N} d_{ij} \times \left[\left[\left(CoE_{(V_{full})} - CoE_{(V_{empty})}\right) \times \frac{U_{(kijt)}}{CV}\right] + \left[CoE_{(V_{empty})} \times VN_{wt}\right]\right] \end{aligned} \tag{3}$$

3.3. Constraints

$$\sum_{t\in\Pi}\sum_{w\in W} Q_{kwt} \le CAS_{(k)} \qquad \forall k \in S \tag{4}$$

$$TN_{(kwt)} \times CT \ge Q_{kwt} \qquad \forall k \in S; \forall w \in W; \forall t \in \Pi \tag{5}$$

$$\sum_{k} Q_{kwt} \le CAW_{(w)} \times z_w \qquad \forall w \in W; \forall t \in \Pi \tag{6}$$

$$Q_{kwt} = \sum_{j\in N} d_{(jkt)} \times \alpha_{iw} \qquad \forall w \in W; \forall k \in S; \forall t \in \Pi \tag{7}$$

$$\sum_{w\in W} \alpha_{jw} = 1 \qquad \forall j \in N \tag{8}$$

$$x_{wjt} \le z_w \qquad \forall j \in N; \forall w \in W; \forall t \in \Pi \tag{9}$$

$$\sum_{j\in N} x_{ijt} = 1 \qquad \forall i \in W \cup N; \forall t \in \Pi \tag{10}$$

$$\sum_{\substack{j\in N\\ i\neq j}} x_{ijt} = \sum_{\substack{j\in W\cup N\\ j\neq i}} x_{ijt} \qquad \forall i \in W \cup N\ \forall t \in \Pi \tag{11}$$

$$\sum_{\substack{j\in W\cup N\\ j\neq i}}\sum_{k\in S} U_{kjit} - \sum_{\substack{j\in W\cup N\\ i\neq j}}\sum_{k\in S} U_{kijt} = d_{(ikt)} \qquad \forall i \in N; \forall t \in \Pi \tag{12}$$

$$\textstyle\sum_{k\in S} U_{kijt} \le CV \times x_{ijt} \qquad \forall i \in W \cup N; \forall j \in N; \forall t \in \Pi \tag{13}$$

$$\sum_{j\in N} U_{kwjt} = \sum_{j\in N} d_{(jkt)} \times \alpha_{jwt} \qquad \forall w \in W; \forall k \in S; \forall t \in \Pi \tag{14}$$

$$\sum_{k\in S} U_{kijt} \le \left(CV - \sum_{k\in S} d_{(ikt)}\right) \times x_{ijt} \qquad \forall i \in N; \forall j \in N; \forall t \in \Pi \tag{15}$$

$$\sum_{k\in S} U_{kijt} \ge \sum_{k\in S} d_{(ikt)} \times x_{ijt} \qquad \forall i \in W \cup N; \forall j \in N; \forall t \in \Pi \tag{16}$$

$$x_{ijt} \le \alpha_{jit} \qquad \forall i \in W; \forall j \in N; \forall t \in \Pi \tag{17}$$

$$x_{ijt} + \alpha_{jht} + \sum_{\substack{w \in W \\ w \neq h}} \alpha_{jwt} \leq 2 \qquad \forall\, i, j \in N / i \neq j\,;\ \forall\, h \in W; \forall t \in \Pi \tag{18}$$

$$VN_{(it)} = \sum_{j \in N} x_{ijt} \qquad \forall\, i \in W; \forall t \in \Pi \tag{19}$$

$$TN_{(kwt)}\,, VN_{(wt)} \in Z^{+} \qquad \forall\, k \in S; \forall\, w \in W; \forall t \in \Pi \tag{20}$$

$$z_{w}\,; \alpha_{jw}\,; x_{ijt} \in \{0,1\} \qquad \forall\, j \in N; \forall\, w \in W; \forall\, i \in W \cup N; \forall t \in \Pi \tag{21}$$

$$U_{kijt} \geq 0; Q_{(kwt)} \geq 0 \qquad \forall\, k \in S; \forall\, w \in W; i \in W \cup N, j \in N \tag{22}$$

Eq. (4) permit do not exceed the capacity of the suppliers. Eq. (5) links the quantity of products delivered into every depot by every distributor and the truck payload. Eq. (6) indicates that no depot's capacity is exceeded by the quantity of products it receives, and if warehouse j is not chosen, no goods are allocated to it. Eq. (7) leads to guarantee that each depot obtains the same quantity of goods as the total request of consumers assigned to this depot. Eq. (8) stipulates that each client be assigned to a one distinct depot. Eq. (9) ensures that the vehicles can only begin the tour from depots that are currently open. Eq. (10) highlights that every client is only visited once. Eq. (11) guarantees that a vehicle visiting a customer node in the second echelon should leave it. Eq. (12) illustrates the second echelon's equilibrium of product flow. Eq. (13) indicates that the amount of cargo on the vehicle shouldn't be greater than its capacity. Equations (14) to (16) show that the vehicle capacity is expected to exceed all the requests from clients that are attributed to the open depot. Equations (17) and (18) indicates that routes with one or more customers must be created, and the customers must be assigned to the appropriate depot. Constraints (19) determines the quantity of small vehicles required to meet demand. Equations (20)– (22) describes each decision variable's nature.

4. Solution approach and results

Numerical simulations based on a real-world case study are presented in this section. The comparison of independent and cooperative cases under single- and multi-objective techniques provides an extensive analysis, taking cost and profit allocation into account. All models were coded in MATLAB. Tests were run on a PC Intel Core i7 processor 2.3 Ghz with 16 Go of memory under the System Windows 11.0.

4.1. Data and information

A record of the last four weeks' worth of client orders has been given to us by the three participants, BG, BL and BB. There is only one shipment per week. The product under investigation is flour, which comes in 25 kg sacks. Every supplier has distinct customers. The two suppliers, Both BG and BL indicate comparable levels of demand and customer sizes. We classify BB as a small supplier and BG and BL as big-size suppliers. Three depots were operated by suppliers BG and BL, and two depots were operated by supplier BB. In summary, 37 points for shipment and 8 possible depot locations have been determined. The travel distances were calculated using the Google Distance Matrix API. We consider groups of similar vehicles and trucks.

Table **2** describes their features. This issue is therefore an extension of the facility location problem, with several distinct firms possessing long-standing distribution centers that could potentially be utilized in the collaboration. We are unable to share sensitive information due to confidentially (e.g., requests, localizations, and costs).

Table 2
Trucks and vehicles characteristics

	Urban vehicle	track
Type	RENAULT-Master FORGON TRACTION L2H3 2,8T	Volvo FL514 4x2 Platform 14 ton
		
Capacity (Bags)	55	250
Speed (km/h)	30	60
(g.CO2/km)$E_{(empty)}$	208	650
(g.CO2/km) $E_{(full)}$	234	780

4.2.Optimization approach

Two scenarios are compared using the created mathematical formulation: the cooperative case (S2_C) and the non-cooperative case (S1_NC). By resolving a single-source 2E-OLRP in the S1_NC, each shipper forms its own transportation network without utilizing common infrastructure or vehicles. Sharing depots and vehicles, S2_C handles the multi-sources 2E-OLRP (3 shippers). We use the cumulative totals across the four-week planned horizon to analyze the results. For analysis, three scenarios will be implemented:

- (C_min) is the solution to the financial function.
- (Em_min) is the solution to the ecological function.
- (Cost_St_Env) Tradeoff between cost and emission where multi-objective model is resolved.

Because of the confidentiality concern, we compare the stand-alone and cooperation scenarios and assess the effect of horizontal collaboration by calculating the proportion of realized savings.

4.3.Experimental results

4.3.1. The Aggregated gains analysis

The problem was initially resolved with the single objective function of minimizing the overall cost. After that, the issue was resolved by taking into account the second objective function, which is to minimize CO2 emissions. Table 3 illustrates the results of comparing the cooperative case to the independent one. Results demonstrate significant cost savings in all collaborative scenarios, with over 15% and 8% savings, successively in the cost minimization case and Emission minimization case. The results show the improvements in ecological impact by the reduction of CO2 emissions with over 12% and 31% savings, successively in the cost minimization case and Emission minimization case. Analyzing other indicators reveals that these positive gaps are relative to the reduction of depots number, travelled distances and vehicles number.

Table 3
Collaborative performance analysis (stand-alone Vs collaboration)

Cases	Cost minimization		Emissions minimizatio	
Scenario	S1_NC	S2_C	S1_NC	S2_C
CO2 emissions (kgCO2)	69417	61022	43789	29814
CO2 Emissions Gaps	- 12,09%		-31,91%	
Cost Gaps	-15,34%		-8,84%	
Depots number Gaps	-40%		-40%	
Total km run Gaps	-19,3%		-25,6%	
Vehicle number Gaps	-15,6%		-17,2%	

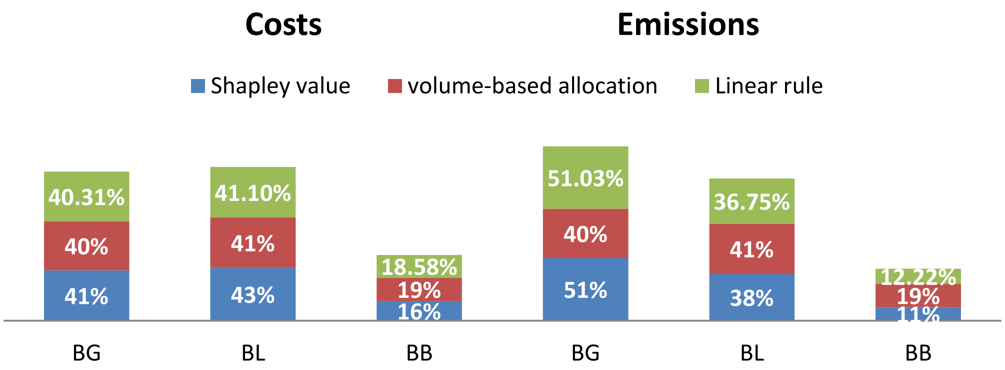
4.3.2. Cost and emissions allocation

We acknowledge that selecting an allocation mechanism requires a case-by-case analysis (Defryn et al., 2014). In this section, we aim to assess individual benefits using several techniques. The Shapley value approach has become more recognized by the industry as a potential best practice, particularly since the European CO3-project introduced the method (Defryn et al., 2016; Cruijssen & BV, 2012). As a result, we advise decision-makers to make a comparison between the basic proportional sharing procedures —particularly the linear rule sharing and the volume-based sharing —with the cooperative game theory, Shapley value method. Gains or costs are allocated using the proportional allocation methods by determining a weight for every participant. The allocation to each player in the linear rule technique is established by averaging the values of all coalitions that contain that player. The core concept of the Shapley value is the notion of each player's marginal contribution to each potential coalition in which they take part. Assuming a player i and an alliance N formed up of sub-alliance S ⊆ N, each of which creates a cost c(S), The Shapley value, is:

$$C_i^{\text{Shapley}} = \sum_{S\subseteq N\backslash i} \frac{|S|!\,(n-|S|-1)!}{n!} * \big(c(S\cup i) - c(S)\big) \tag{23}$$

Fig. 3 shows, for each supplier, the percentage of allocated costs and emissions by different allocation mechanisms. In the two extreme cases, the investigated allocation techniques assign fewer expenses and carbon to the smallest participant, BB. Using the linear rule approach, the participants with greatest individual values receive the biggest relative proportion of the coalition cost/emissions (BL for cost and BG for carbon emissions). This method considers individual expenses and carbon to calculate the proportional weighting of each participant. In the volume-based method, the participant with the highest volume receives the greatest proportion of the collective cost or emissions. The volume-based method attributes the two values based on shipped volume. The Shapley value technique employs the collaborators' participation to all probable sub-coalitions. This method attributes the largest part of the cost or emissions to partner BG, except for the C_min case, where more cost was attributed to partner BL due to his higher stand-alone cost.

C _min case



Em _min case

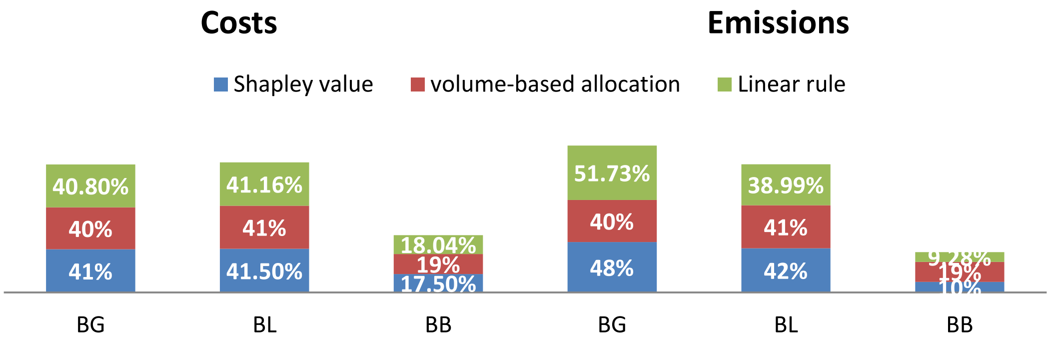
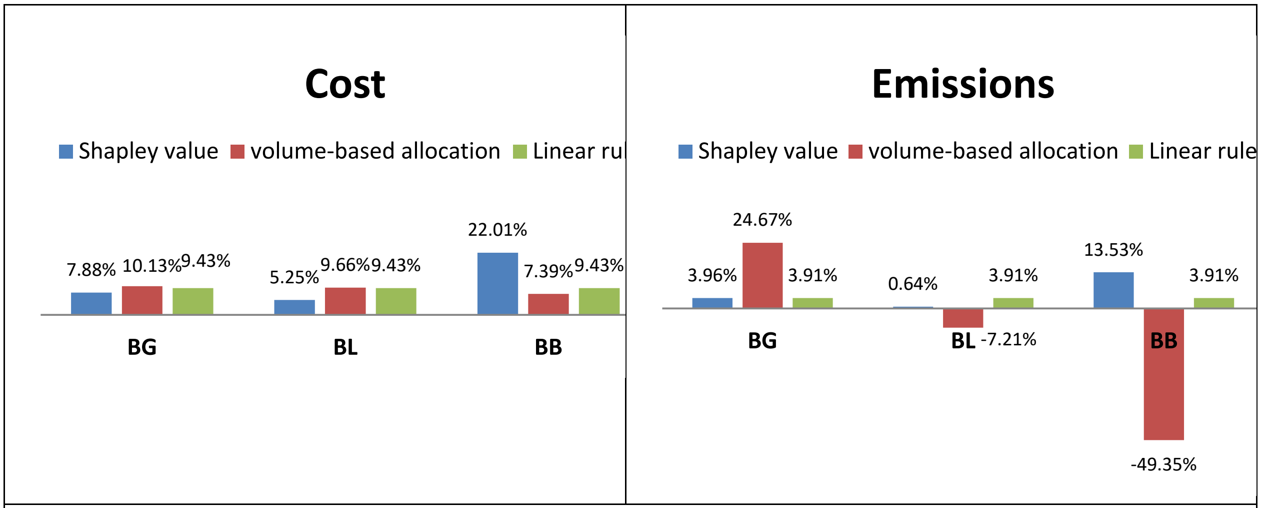


Fig. 3. Sharing of alliance costs and carbon dioxide emissions adopting various approaches in both extreme scenarios

Figure 4 illustrates the individual costs and emissions gains allocated by the different allocation methods. The linear rule and Shapley value method don't attribute negative gains. The linear rule leads to equal attribution of gains to different partners. The volume-based approach credits to participant BB unfavorable economic and environmental gains in two different situations and, to participant BL, a negative ecologic gain in the C_min case

The proportional cost allocation techniques are facile for conveying to the partner, but they have major shortcomings. The equal gain allocated to partners with the linear rule is evaluated as not fair. Logically, the larger partner contributes better to the contract's negotiation. The volume-based allocation method can contribute to the loss compared to a stand-alone scenario. This incites partners to participate in small volumes. Furthermore, the technique ignores the regional distribution of customer demand locations. The method is incapable of ensuring an equal and equitable attribution of the advantages of the cooperation. The Shapley value is computed utilizing each collaborator's residual values in any potential sub-coalitions. As a result, collaborators are motivated to collaborate together because the approach guarantees consistency and equity amongst them.

Gaps values in C _min case



Gaps values in Em _min case

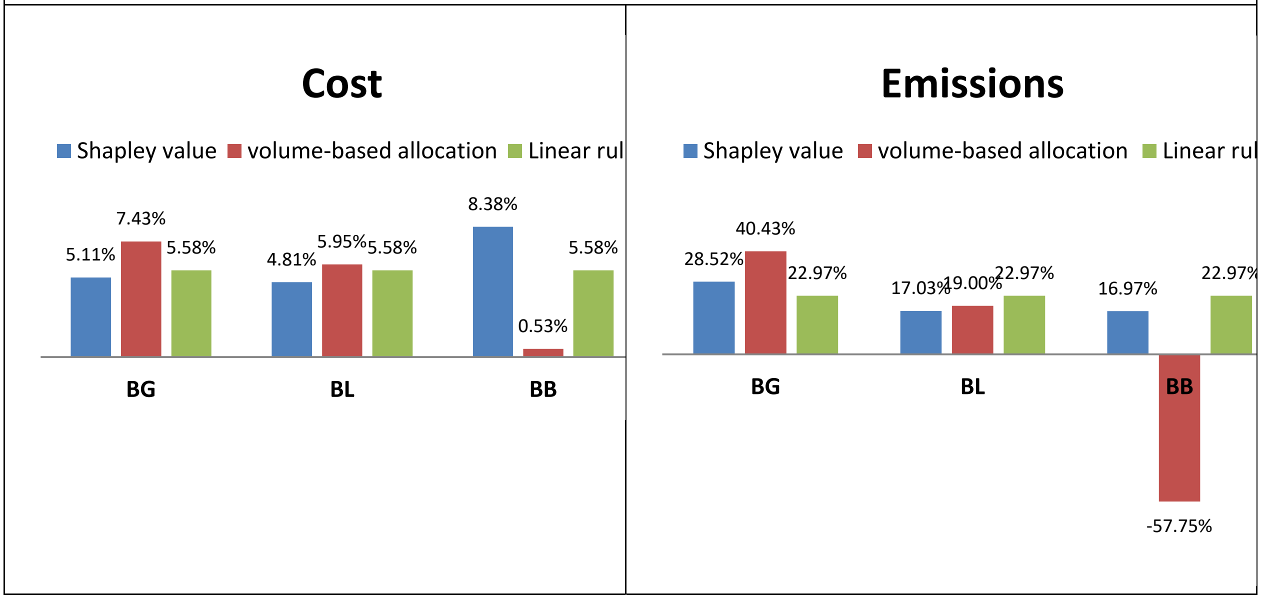
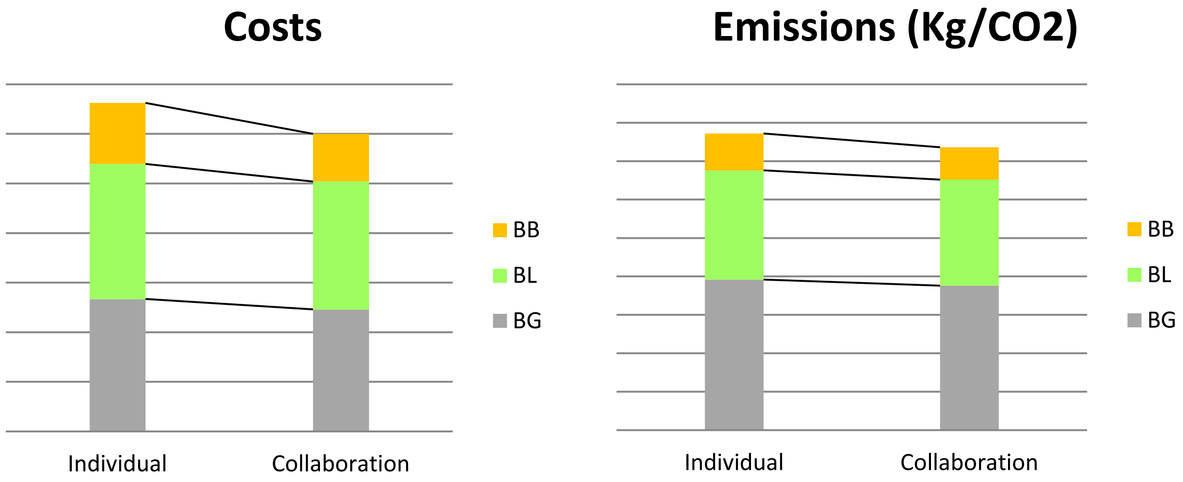


Figure 4. Individual cost and emissions gains allocated by the different allocation methods in C_min and Em_min cases

The three key characteristics of the Shapley value method are outlined below. The Shapley value keeps the players from regretting their decision and keeps them from engaging in prolonged debates and negotiations; Uniqueness: The players like having a unique solution since it eliminates the possibility that another option could be superior or dismissed; Fairness: this is crucial in any situation involving sharing (Defryn et al., 2014). Therefore, in the present case study, we choose to share the cooperative gains using this approach. Fig. 5 focuses on the individual gains generated after collaboration using the Shapley value method as allocation mechanism.

C _min case



Em _min case

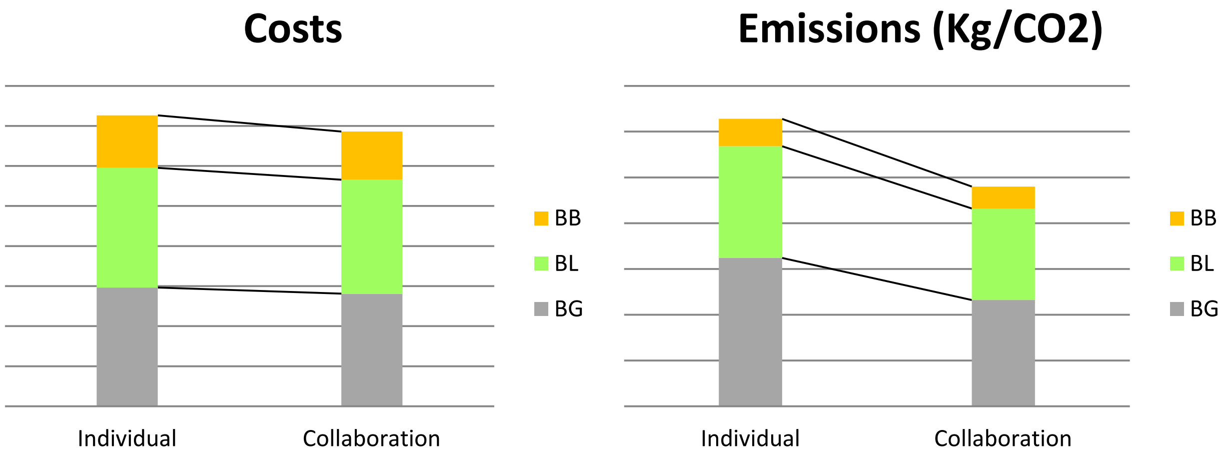


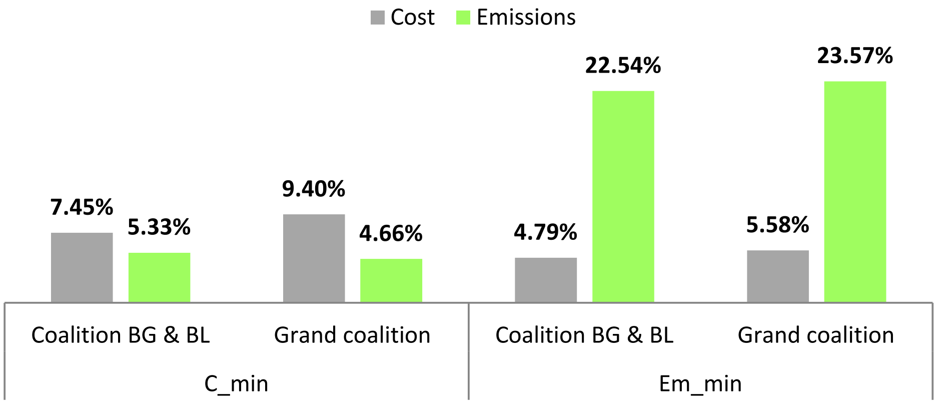
Fig. 5. Costs and Emissions before and after collaboration using Shapley value method.

The average reduction in overall cost in the Em_min situation is between [4.5%, 9%], however when the C_min case is considered, these values rise to [5.5%, 23%]. The range of gains for carbon emissions in the Em_min case is [17%, 29%], compared to the range [0.5%, 14%] in the C_min case. This is because reducing costs necessitates establishing cheaper depots, which entail greater distances, however reducing emissions necessitates opening more expensive depots, which entail shorter distances. The biggest gainer from the partnership was the small supplier, BB. In the C_min instance, this partner made a 22% economic profit; in the Em_min instance, it made a 13% ecological benefit. Larger suppliers have more demand and client numbers, which results in higher expenses and emissions attributed to them.

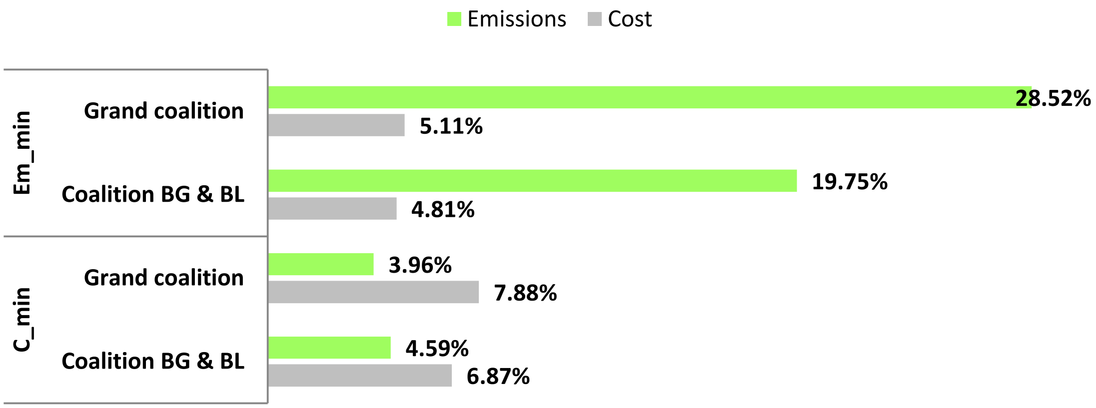
4.3.3. Evaluation of the inclusion of supplier BB in the coalition

The two companies BL and BG are currently working together, creating a buying coalition, and they intend to include other partners, as stated in the case study description. Each partner wants to choose partners who will help them maintain their market position. Therefore, we evaluate supplier BB's economic and environmental contribution to the coalition under study. We simulate the sub-coalition that can be formed by, only, BG and BL. For the two situations (C_min and Em_min), we compute the highest and lowest solutions for the non-cooperative case. Next, an assessment is made independently. scenario and the cooperative scenario (CS). Fig. 6 presents the acquired results. The large coalition outperforms the sub-coalition created by BG and BL in every scenario, apart from carbon emissions in the C_min case (Fig. 7.a). Suppliers BG and BL are more interested in evaluating their individual gains after the entry of supplier BB into the coalition. Costs and carbon emissions are allocated using the Shapley value. Fig. 7.b and Fig. 7.c illustrate the obtained results. Results demonstrate that collaboration with suppliers BB is, economically, more advantageous than a two-partner coalition. On the contrary, this collaboration will make emissions savings inferior to those of a two-partner coalition. BG is the only supplier that increases its ecological savings in Em_min case. Recognizing that economic concerns take priority over environmental ones, we can deduce that the coalition consisting of three partners is more profitable, and supplier BB's arrival may enhance partners' earnings.

(a) Aggregated gains



(b) Supplier BG



(c) Supplier BL

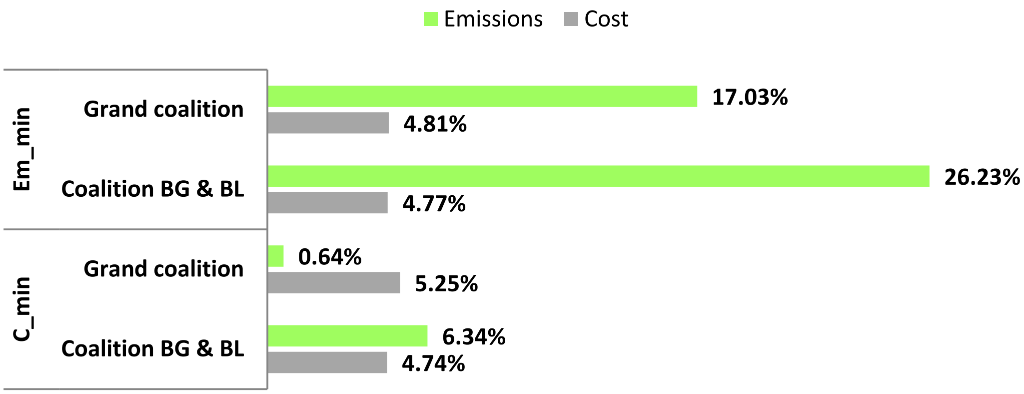


Fig. 6. Comparison of the aggregated and individual gains generated by the sub-coalition and grand coalition.

4.3.4. Trade-off analysis

The economic and ecological objective functions can be solved optimally thanks to the single-objective resolution. To establish a compromise between competing goals, the distribution network design should take several factors into account. Attempting to maintain a balance between the ecological and economic effects, decision makers are unsure of the relative relevance of each goal. Multi-objective problems can be solved using a variety of techniques, including exact and meta-heuristics. One of the popular exact solution techniques for optimization problems is the Epsilon-constraint method (Mavrotas, 2009). For small-size examples, the ε-constraint approach is used to find the appropriate Pareto-fronts. Below is a list of stages in the constraint method:

1. Select the primary goal from among the objective functions.
2. Determine which of the objective functions should be the primary goal for each iteration of the problem's solution, then report the best solutions.
3. Create a table for the values of $\varepsilon_2, \ldots, \varepsilon_n$ by dividing the interval between other objective functions into a certain number of splits.
4. For each of $\varepsilon_2, \ldots, \varepsilon_n$, solve the problem independently.
5. Provide the Pareto solutions that were identified.

As an example, *t* main goal function is the first objective function (*F1*). the second objective function (*F2*) is restricted to different values of ε and added to the list of constraints:

min F1

s.t. Constraints

$F2 \leq \varepsilon$

$F2\ \min \leq \varepsilon \leq F2\ \max \quad (24)$

The findings of the cooperative single-goal method are utilized to determine the upper and lower limits for the second objective. By decreasing the value of ε by one step at a time, we obtained ten instances. We get to the Pareto frontier in Fig. 8 after considering the trade-off between the objective functions.

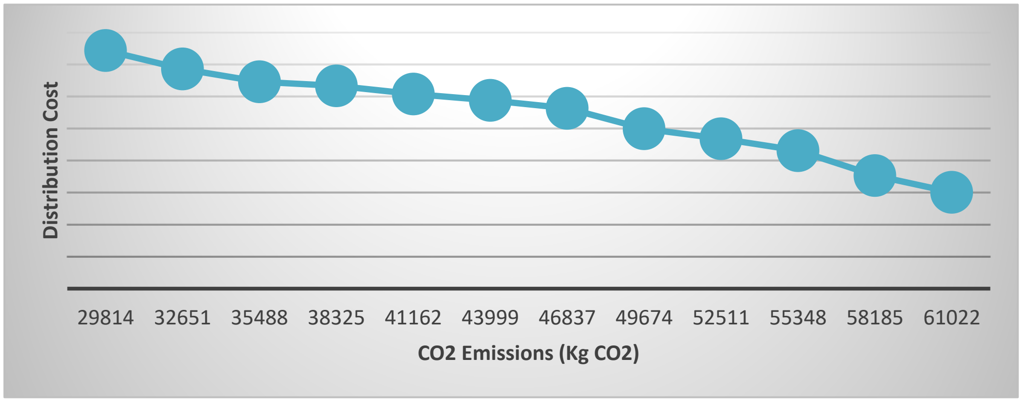


Fig. 7. Trade-off between CO2 emissions and Distribution cost

Fig. 7 shows that as the maximum level of CO2 emissions declines, the total cost of distribution grows up. In general, the enforcement of emission restrictions, whether voluntary or mandated by law, compels distributors to look for alternate transportation plans through horizontal cooperation. In terms of comparability, Fig. 8 shows the compromise between accumulated carbon reductions and rises in transportation costs when the supply chain is optimized based on cost. Partners can use this representation to define the monetary effect of their ecological purpose. For instance, in order to achieve the goal of reducing carbon emissions by more than 18.6%, the partners would need to contribute 8.26% of the total cost in the C_min scenario. This example shows how different solution trade-offs that lower CO2 emissions while keeping operating expenses under control can be examined by employing a multi-objective approach. Following this phase, the partners will be generally aware of how ecological and economic issues are traded off. and will need to decide on a favored stance that ensures the coalition's sustainable viability.

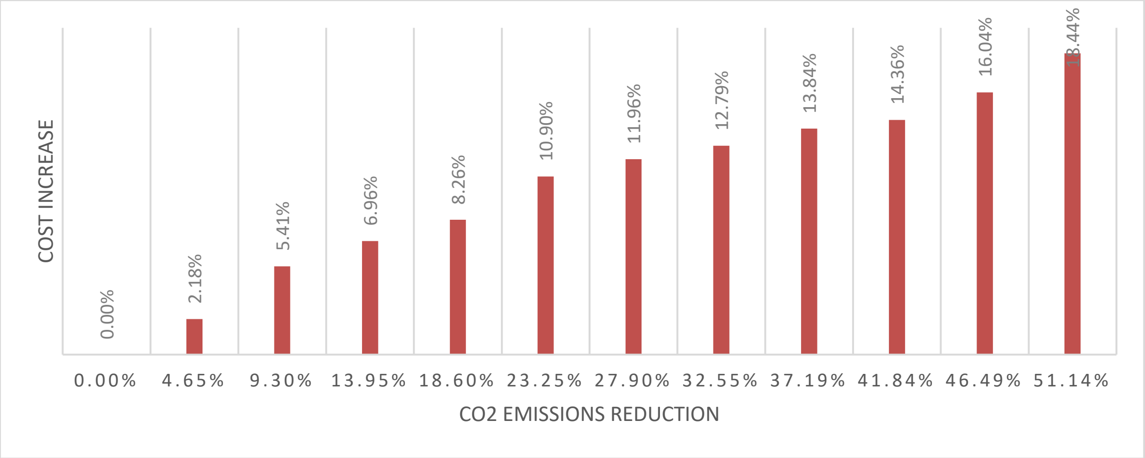


Fig. 8. The compromise between accumulated carbon reductions and rises in transportation costs.

5. Conclusion

Nowadays, most enterprises acknowledge that improving the supply chain is critical for raising income and gaining position in the market. The concept of horizontal collaboration has become a key driver of revolutionary change in the field of supply chain management. To address common difficulties, horizontal collaboration entails strategic partnership and coordination across companies operating at the same level of the supply chain. Given this, it is imperative that companies recognize the value of horizontal collaboration as they attempt to find creative solutions to deal with the complexities of contemporary supply chain dynamics. This study proposes an initial decision-making tool to evaluate ecological and financial impacts of cooperative freight distribution. It assesses the potential of involving FLP and VRP issues in cooperative projects for environmentally conscious freight transportation. The study uses a multi-objective, two-echelon open location routing problem (2E-OLRP) to evaluate the benefits to individual shippers and the suitability of partners involved in the alliance. The horizontal collaboration enables to combine resources and take advantage of economies of scale. Collaborating companies can have access to pooled infrastructure, warehouse facilities, and transportation fleets by jointly utilizing distribution centers. All stakeholders benefit financially and environmentally from this cooperative resource use. By considering not just economic variables but also environmental factors, the Open LRP may help firms plan and optimize their collaborative supply chains in a more sustainable manner. This may lead to increased stakeholder relations, decreased environmental effect, and higher sustainability performance. Improved transportation and distribution optimization are fostered by horizontal collaboration using the Two Echelon Logistics Distribution System. Increased load efficiency at the CDC can save transportation costs by combining shipments from many cooperating companies.

Some managerial insights are offered by this study. The paper explores the challenge it is to construct a supply chain that both draws on the advantages of horizontal collaboration and makes it simple. It is a challenge for managers to adopt a more integrated and interconnected strategy and to reconsider the existing supply chain structures. The proposed design problem encourages managers to consider factors such as network configurations, cost sharing mechanisms, and sustainability. The paper gives useful managerial insights by providing a structured framework for dealing with these issues, which can help decision-makers use horizontal collaboration as a powerful instrument to achieve increased efficiency. This proactive approach to supply chain design emphasizes the value of managerial vision in navigating the complexities of cooperative supply chain activities, which is in line with the paradigm change toward more agile and adaptive supply chain models.

We aim to include social factors in our next study to encourage businesses to adopt cooperative strategies. We also intend to develop meta-heuristic algorithms for addressing complex collaborative scenarios, extending the suggested model to include uncertain settings in supply chain processes, such as demand fluctuations or transportation delays.

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