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A cost- effective collaborative inventory management strategy between non-competitor companies - A case study

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Abstract

This paper introduces a collaborative strategy in the supply chain that demonstrates potential to reduce management inventory costs, through the coordinated replenishment of multiple items from non-competitors vendors. The proposed approach is an extension of the classical joint replenishment problem (JRP) denominated as stochastic collaborative joint replenishment problem (S-CJRP) since considers normally distributed demand and real world constraints. This research presents two main problems: the first consists in determining the frequency in which each vendor should replenish its products considering a limited transport and storage capacity. A heuristic procedure has been used as effective methodology for solve it. The second problem deals with the problem of allocate the benefits given by the collaboration in a viable and stable way. This problem was modeled as a cooperative game for ensuring fairness among participants. The Shapley Value was used as a method for allocation, which allows a balance between the contribution and gain sharing for the players. A study case is presented to illustrate the effectiveness of this strategy, providing economics benefits.

Keywords
Stochastic joint replenishment problem, collaboration in supply chains, multi-product inventory model, Shapley value.

1. Introduction

The global competition, forces companies to meet the product demands at an increasingly lower price. In particular, the retailers companies are forced to manage efficiently their inventories, considering that a good management could be the base to a competitive advantage. However, for companies with limited resources, competition may be non-viable. For example, the lake of warehouse space, transport capacity or budget, leave aside the possibility of access to better 3pl services charges, supplier quantity discounts or the exploitation of economies of scale.

The inventory replenishment process implies incurring in two types of costs: a setup cost and a holding cost (Hax & Candea, 1983). In the first one, there are elements of a fixed nature. Therefore, it makes sense to replenish jointly multiple items rather than one. Including several items in an order allows the exploitation of economies of scale, so savings could be achieved (Silver, 1974). This problem is widely recognized in the literature as the Joint Replenishment Problem (JRP). Since its appearance in the works made by Starr, M. K., & Miller (1962), the JRP has been recognized by its potential of application in real scenarios. Different solutions and variations of the problem have been proposed for more than five decades. However, the greatest effort has revolved around finding the optimal solution. Most authors have proposed heuristics as solution methods since the JRP is a NP-hard problem (Arkin, Joneja, & Roundy, 1989). Aksoy & Erenguc (1988) reported a literature review of the solution methods available at that time. Subsequently, Khouja & Goyal (2008) presented a new review of the developed researches between 1989 and 2005. Within the available literature, there are some methods that stand out for their efficiency. However, the better results are achieved by the heuristic proposed by (Kaspi & Rosenblatt (1991) called RAND, the genetic algorithms (GAs) (Khouja, Michalewicz, & Satoskar, 2000) and differential evolution (DE) introduced by Storn & Price (1997) and applied for the JRP by Wang, He, Wu, & Zeng (2012).

The aim of this paper is to demonstrate the potential of collaborative practices in inventories as a strategy to reduce costs. In order to illustrate these benefits, we expose a study case of four non-competitors importer companies with limited resources. The proposed approach includes a logistic strategy involving a real inventory problem that can be considered as an extension of the classic JRP. The biggest difference between these models is that considers multiple buyers and suppliers, stochastic demand, warehouse and transport capacity constraints. On the other hand, buyers share information and resource in order to achieve economic benefits. This model has been called as the Stochastic Collaborative Joint Replenishment Problem (S-CJRP). This situation of collaboration can be modeled as a collaborative game and the greatest difficulty is to ensure stability among players, i.e., satisfy their interests simultaneously. The Shapley value was used as a mechanism for sharing the benefits obtained through collaboration. The structure of the paper is as follows: Section 2 presents a framework of the concept and applications of collaboration in the supply chain, Section 3 introduces a case study, and then the Section 4 introduces the mathematical model. Section 5 deals with the S-CJRP solution method. Section 6 exposes the cost allocation technique and Section 7 illustrates the case study solution. Finally, Section 8 summarizes the discussion and conclusions.

2. Collaboration in the Supply Chain

The collaboration in the supply chain can be defined as the joint work between two or more enterprises in order to create a competitive advantage, which in an individual way could not be achieved (Simatupang & Sridharan, 2005). In particular, the strategies concerned to collaborate in inventories have received special attention, considering the positive effect that could have over the effectiveness and profitability of the supply chain. The first appearance of this topic dates to the middle of the 90's through the use of strategies with the aim to mitigate the demand uncertainty and the bullwhip effect, such as collaborative planning forecasting replenishment (CPFR) (VICS, 1998), vendor management inventory or the continuous replenishment programs (CRP). Since its inception these strategies have been extensively implemented by practitioners and academics (Ireland, R. & Bruce, 2000; Småros, Lehtonen, Appelqvist, & Holmström, 2003). In inventories, the collaboration can be developed in horizontal, vertical or a lateral way (Chan & Prakash, 2012). In this sense, several models have been proposed. Özen, Sošić, & Slikker (2012) presented a decentralized inventory model compose by a manufacturer, a warehouse and a n retailer. The authors demonstrated that through sharing information better forecasting can be calculated, improving the efficiency of all the chain. Bartholdi & Kemahlioğlu-Ziya (2005) propose a centralized inventory model where one manufacturer supplies two retailers who are competitors. The strategy demonstrated a potential inventory cost reduction. Yu (2010) reported a model where a single supplier and costumer in a joint effort achieve an inventory cost reduction of perishable goods and reduce the breach of orders by non-compliance. Zhang, Liang, Yu, & Yu (2007) implemented a series of transport policies that seek to lower the inventory level for four costumers, demonstrating that their model can reduces the holding cost of all participants. Other references models are reported by Kelle, Miller, & Akbulut (2007); Zavanella & Zanoni (2009).

3. Case study

This section refers to the case of four auto parts retailer companies that operate in Colombia. These retailers are not market competitors, but have sales points located a few meters from each other. In addition, the companies import their main products from suppliers located in the east coast of United States. All of them use a rented warehouse from where supply their sales point several times in the month. Two of the four companies have a limited warehouse capacity, but acquiring extra space is non-viable, a lot less an own warehouse. The regular replenishment process begins with an order attended by supplier (Figure 1), who delays to ship the cargo close to one week for the four cases casually. The incoterm used is FOB, so the supplier incurs in the cost and responsiveness to board of ship where a 3pl receive the cargo. After is send to a final destination in Colombia.

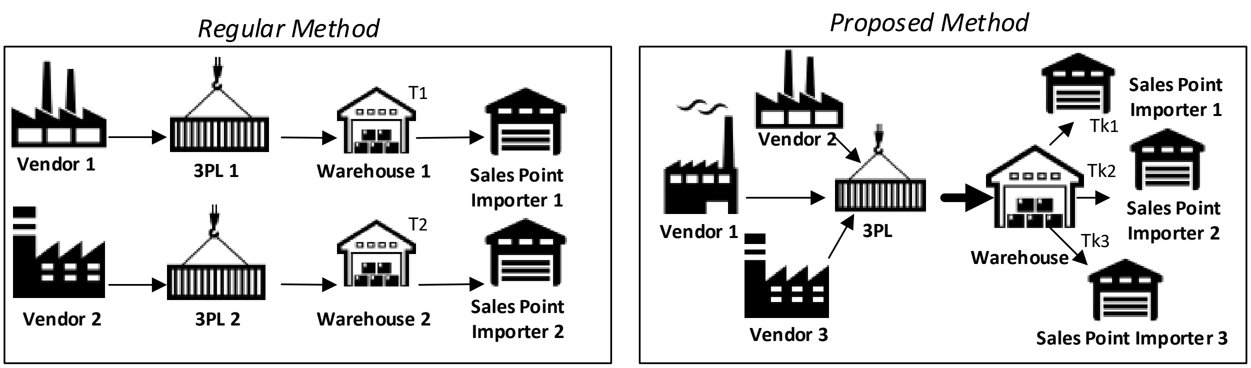

Figure 1: Regular replenishment method vs. the proposed method.

The proposed method (Figure 1, right) starts with deliveries from the different suppliers consolidated using a 3pl to converge in a unified cargo flow towards collaborating importers. They constitute the role of the "players", who restock his inventory with a frequency Tk_i, in a quantity $Q_{i=}D_i\,Tk_i$, where k_i is an integer and D_i is the demand of the item family i. Once the cargo is consolidated, it is sent by sea to a destination port near importers facilities. Furthermore, importers share storage facilities and costs. The scope of the proposed schema ends up with the breakdown of the cargo flow back to separate family items. As expected, collaboration directly affects the holding cost (h) and the ordering mayor cost (S). The former could be considerably reduced due to economies of scale, while the latter could be increased by the cost of implicit co-ordination in the cargo consolidation. For practical purposes, we have considered different scenarios. We vary the parameters of cost in order to evaluate the effectiveness of the strategy.

4. Proposed extended mathematical model

Although the JRP is a model with a high applicability in real life problems (Khouja & Goyal, 2008), some of its assumptions are debatable. One of them is considering demand as a deterministic variable and not as stochastic because this simplifies the work. In this research, demand is considered stationary and forecast errors are normally distributed. The mains facts to justify this affirmation are based on the works of Eynan & Kropp (1998); Peterson & Silver (1979); Silver et al. (1998) as follows: (1) empirically, normal distribution fits better than other distributions to the demand, (2) adding the forecast errors of many periods, a normal distribution would be expected due to the central limit theorem and (3) the normal distribution allows analytically tractable results. Another assumption is to consider available quantity discounts. It does not affect the model realism; however, some authors present alternative solution to this (Moon, Goyal, & Cha, 2008). Likewise, the assumption of not considering the shortage is not critical either. In the worst case, it leads to a delay in the supply (Taleizadeh, Samimi, & Mohammadi, 2015). The classic JRP is an unrestricted problem, notwithstanding real life situation are limited by different types of constraint (Goyal, 1975). The S-CJRP considers constraints and stochastic demand in the same model. The most classic and current works develop just one assumption. In this research we considers six: Shortage is not allowed, quantity discounts are not available, demand normally distributed, limited warehouse capacity, limited transport capacity and the cargo is compatible and non-perishable. The last assumption is a condition to carry out a feasible cargo consolidation (see Ai, Zhang, & Wang, 2017).

The model notation is defined:

TC	Total annual cost (ordering, holding and transportation costs)	k_i	Positive integer multiplier of T for the item i; $i \in I$
n	Number of item families	A	Cost of a full transport/container unit
I	Set of family items; $I = \{1,2,3, \dots, n\}$	W	Maximum capacity of a transport unit
D_i	Annual demand rate of item i; $i \in I$	w_i	Weight/volume per unit of item i; $i \in I$
S	Major ordering cost	B	Minimum storage capacity required
s_i	Minor ordering cost of item i; $i \in I$	σ_i	Standard deviation of item i; $i \in I$
T	Time of reference between two consecutive replenishments	Z_i	Multiplier of σ_i, determines the service level for the item i; $i \in I$
h_i	Holding cost of the item family i; $i \in I$	Lt_i	Lead time of item i; $i \in I$

It should be noted that S is independent of the number of items in an order. These costs correspond to the ones pertaining to the number of containers, i.e., fixed costs due to the processing of documents, costs of preparing and receiving orders, and materials management. On the other hand, s_i is incurred only when the item i is included in an order. It is related with the costs of manipulation, processing and additional efforts due to disaggregate cargo. The reported strategies for solving the JRP are divided in two (Khouja & Goyal, 2008): a direct grouping strategy (DGS) and the indirect grouping strategy (IGS). For the first one, items are assigned into a predetermined number of sets and the items within each set are jointly replenished with the same cycle. The second one consists in determining a fixed regular time interval per item in which items are replenished in a quantity large enough until the next replenishment. The time intervals per item are given by an integer multiple of a common time interval and items with the same integer multiple are jointly replenished, so that groups are indirectly formed. Eijs, Heuts, & Kleijnen (1992) assert that IGS outperforms DGS due to higher ordering costs because many items can be jointly replenished when using an IGS. In this research, the JRP is solved using IGS strategy.

The proposed objective function is composed by four components. The first one refers to the annual ordering cost:

$$\frac{S}{T} + \sum_{i \in I} \frac{s_i}{k_i T} = \left(S + \sum_{i \in I} \frac{s_i}{k_i} \right) / T \tag{1}$$

The second represents the annual holding costs, as follows:

$$\sum_{i \in I} \left(\frac{D_i k_i h_i}{2} \right) T = \frac{T}{2} \sum_{i \in I} D_i k_i h_i \tag{2}$$

The third refers to the annual holding cost by the security stock:

$$\sum_{i \in I} Z_i \sigma_i h_i (\sqrt{Lt_i + Tk_i}) \tag{3}$$

The last in (4) refers to the annual transport cost:

$$\sum_{i \in I} \left(\frac{w_i D_i k_i T A}{W k_i T} \right) = \sum_{i \in I} \left(\frac{w_i D_i A}{W} \right) \tag{4}$$

The expression in (3) represents the quantity of security stock enough to guarantee a specific service level linked with Z_α, where the complement of alpha $(1 - \alpha)$ is the probability of shortage between a cycle time. The expression in (4) indicates that the transportation cost is independent of the basic cycle time. Thus, from the aggregation of (1), (2), (4) and (4), the cost objective function of the model is obtained in (5). The proposed extension for the JRP model is introduced as follows:

$$\begin{aligned} &Minimize\text{: } TC(T, k_1, k_2, \dots, k_n) \\ &= \left(S + \sum_{i \in I} \frac{s_i}{k_i} \right) / T + \frac{T}{2} \sum_{i \in I} D_i k_i h_i + \sum_{i \in I} Z_\infty \sigma_i h_i (\sqrt{Lt_i + Tk_i}) + \sum_{i \in I} \left(\frac{w_i D_i A}{W} \right) \end{aligned} \tag{5}$$

$Subject\ to$:

$$\sum_{i \in I} D_i w_i T k_i + \sum_{i \in I} Z_i \sigma_i (\sqrt{Lt_i + Tk_i}) \le B \tag{6}$$

$$\forall i \in I$$

$$T > 0; \ \ K_i\text{: } integer$$

Constraints (6) are concerned with the warehouse limited capacity. It should be noted that the objective function in (5) depends on the variables T and k_i. For a single product case ($n = 1$) the expression in (5) must be modified deleting the si and k_i.

5. Proposed heuristic method to solve the SJRP

The stochastic version of the joint replenishment problem (SJRP) has not been extensively studied as the deterministic one. Two main types of policies have been proposed for solving the SJRP: periodic replenishment policy and can-order policy (Johansen & Melchiors, 2003). The first one was developed by Atkins & Iyogun (1988) for Poisson demands. It consists in stock up the inventory to a quantity M_i each review interval T_i. On the other hand, in a can order policy a stock up is made when an item reached the level must-order m_i in a quantity enough to reach the level M_i. All items that have the level can-order c_i when an order is trigger can stock up to $M_{i.}$ Pantumsinchai (1992) developed a comparison between 3 methods: can order policy, a modified version of the periodic review (MP) (Atkins & Iyogun, 1988) and a policy proposed by Renbeg and Planche (1967) denominated: A, M. The last one consists in monitoring the aggregate inventory and triggers an order to M for all items when a level A is reached. In conclusion, A, M and MP policy have a comparable performance. However, A, M has a better performance than can order policy in problems with high ordering cost, small number of products and low shortage cost. Can order policy just has a better performance in problems with small ordering costs. Another variations of SJRP are provided by Minner & Silver (2005) and Nielsen & Larsen (2005). The first proposed a solution considering continuous review, Poisson demand and constraints through a semi-Markov technique. The second used Markov decision theory to obtain a solution procedure to evaluate the costs in continuous review under Poisson demand and aggregate inventory. In this paper we develop a extention of the heuristic made by Eynan & Kropp (1998) for demand normally distributed, and valid for periodic review models usding IGS strategy. The procedure is presented as follows

$\boldsymbol{Step\ 1}.\ Determine$:

$$T_i^* = \sqrt{2s_i/h_i\left(D_i + \frac{Z_\infty \sigma_i}{\sqrt{Lt_i + T_{0i}}}\right)},\ Where\ T_{0i} = \sqrt{2s_i/h_i D_i}\ \ i = 1, \dots, n.$$

$\boldsymbol{Step\ 2}.\ Identify\ the\ item\ with\ the\ lowest\ T_i^*. This\ item\ will\ be\ denoted\ as\ item\ 1, k_i = 1$

$\boldsymbol{Step\ 3}.\ Solve$:

$$T = \sqrt{2(S + s_1)\Big/h_1\left(D_1 + \frac{Z_1 \sigma_1}{\sqrt{Lt_1 + T_0}}\right)},\ Where\ T_0 = \sqrt{2(S + s_1)/h_1 D_1}$$

$\boldsymbol{Step\ 4}.\ k_i = q\ (integer)\ such\ that\ \sqrt{(q-1)q} \le \left(\frac{T_i^*}{T}\right) \le \sqrt{(q+1)q}\ \ i = 2, .., n.$

$\boldsymbol{Step\ 5}.\ Compute\ the\ new\ cycle\ time\ and\ select\ the\ minimum\ between\ T_A\ and\ T_B$

$$T_A = \sqrt{2\left(S + \sum_{i=1}^{n} \frac{s_i}{k_i}\right) \Big/ \sum_{i=1}^{n} h_i k_i \left(D_i + \frac{Z_\infty \sigma_i}{\sqrt{Lt_i + k_i T_0}}\right)}, \ Where \ T_0 = \sqrt{2\left(S + \sum_{i=1}^{n} \frac{s_i}{k_i}\right) \Big/ \sum_{i=1}^{n} h_i k_i D_i}$$

T_B *can be calculed using the procedure presented to continue*:

begin
$j \leftarrow 0$
$t_j \leftarrow \frac{B}{\sum_{i=1}^{n} D_i w_i k_i}$
$d \leftarrow Precision$
while $\left(\beta(t_j) > B\right)$ **do**
$j = j + 1$
$t_j = t_{j-1} - d$
end
$T_B \leftarrow t_{i-1}$
end

Where:

$$\beta(t_j) = \sum_{i \in I} D_i k_i w_i t_j + \sum_{i \in I} Z_i \sigma_i (\sqrt{Lt_i + t_j k_i})$$

***Step* 6.** *Repeat steps 4 and 5 as necessary or until the overall total cost as determined in the objetive function (5) yields only marginal differences between succesive iterations.*

The T selected in the step 5, is optimal. The proof is presented to continue and adaptedt from Moon & Cha (2006):

Considering $T_A \leq T_B$, $TC(T)$ *is a convex function in the interval* $[0, T_B]$. *Then, the optimal basic cycle time is* $T_{opt} = T_A$. *Otherwise* $T_A \geq T_B$, *as* $TC(T)$ *is a decreasing function in the interval* $[0, T_B]$. *It is possible to ensure that the optimal basic time* $T_{opt} = T_B$.

6. Solving the cost allocation problem

This collaborative strategy can be analyzed as a cooperative game, thus a coalition formation between players is allowed. Coalitions are possible because it is assumed the interest of players eager to negotiate agreements satisfying their interests in a rationally way (Myerson, 1991) also, they expect to keep working together in a medium and long term. For a coalition $S \subseteq N$, where N is the set of all players, there is an expected value of the benefits obtained calculating the characteristic function $v(S)$ from item aggregation of players conforming S. The assignment φ_i of an entrance fee for each player to join a coalition must meet their own expectations. If for any reason a player has an incentive to form a coalition different from the proposed one, it is expected for such player to leave the coalition, introducing instability. Consequently, it is desirable to determine a dominant allocation that provides stability. To ensure this condition, the vector φ must belong to the core of the game. The Shapley Value (Shapley, 1953, 1952) formula guarantees a solution in the core of the game under the compliment of tree axioms described as follows:

I. Symmetry:

$$\Delta_i\,(S) = \Delta_j(S)\;for\;all\;S \subseteq N \qquad (7)$$
$$\varphi i(N,v) = \varphi_j\,(N,v)$$
$$where\;\Delta_i\,(S) = v(S\,\cup\{i\}) - v(s)$$

For our interest, this axiom guarantee that two player with equal power would receive the same allocation. This only depends of his contributions.

II. Efficiency:

$$\sum\nolimits_{i\,\in N} \varphi_i\,(N,v) = v(N) \qquad (8)$$

This axiom makes sure that the allocation allots the total of benefits between players; a player who is not in the coalition does no receive anything.

III. Linearity:

$$\varphi_i(v+k) = \varphi_i(v) + \varphi_i(k) \qquad (97)$$

The third axiom establish, if the players play two different games with value functions v and w, then the total Shapley value allocation to player i is the same as if the players were to play a game with value function $v + k$. Finally, after considering the three axioms, the Shapley Value formula is introduced to calculate φ_i, as follows:

$$\varphi_i(v) = \sum_{S\,\subseteq N-\{i\}} \frac{|S|!\,(|N|-|S|-1)!}{|N|!}\,(v(S\,\cup\,\{i\}) - v(S)) \qquad (10)$$

In this expression, all $|N|!$ orders for a player to integrate a coalition are equally likely, as the number of possible arrangements belonging to S is $|S|!$, meanwhile the number of possible arrangements of the players that make up a coalition after i is $(|N|-|S|-1)!$. Then the probability that i integrates S coalition is $\frac{|S|!(|N|-|S|-1)!}{|N|!}$. The aim is to obtain the expected value of the payment; hence each marginal contribution $(v(S\,\cup\,\{i\}) - v(S))$ is multiplied to its corresponding probability.

6.1 A proposed heuristic to integrate SJRP with Shapley Value.

Determining an allocation through Shapley Value may involve a large number of calculations, since is necessary to determinate $2^{|N|}-1$ characteristic functions that represent the expected value of the payment of all possible games over N, even when $|N|=1$. This work could be non-viable if each one characteristic function must be calculated with a particular function or different variables; considering that growth of these functions is exponential. This paper presents a generic function in (5) which is applicable to any set of players. It is necessary just know the value of his parameters. The solutions are provided by the heuristic presented in Section 5, which are the raw material to calculate the Shapley Value using the next proposed heuristic:

$\boldsymbol{Step\ 1}$: $Initialize\ parameters$
$\boldsymbol{Step\ 2}$: $Determine\ all\ possible\ coalitions\ Si\ over\ N$
$\boldsymbol{Step\ 3}$: $For\ i = 1{:}\,2\text{^}|N|\ -1$
$Calculate\ V\ (Si) using\ the\ SJRP\ heuristic\ by$ Eynan & Kropp (1998)$, with$:
$Dj, hj, W, wj, S, sj, A, \sigma j, zj, H, where\ j = 1,2,3, \dots, |Si\,|$
$\boldsymbol{Step\ 4}$: $Calculate\ the\ Shapley\ Value\ using\ all\ V(Si)$

7. Case study solution

With the purpose of verifying the effectiveness of the proposed strategy, the model was tested considering the current parameters of four companies (Section 3). In addition, 250 problems were simulated in 5 groups of 50. These emulate positive and negative scenarios for companies, as described below:

- *Low demand:* Corresponds at pessimist scenario where the demand decreases between 0.2 and 2 standard deviation. All other parameters remain constant.
- *High Demand*: It is positive scenario where the demand increase decreases between 0.2 and 2 standard deviation. All other parameters remain constant.
- *Low Costs:* It is a positive scenario; the mayor cost (S), minor costs (s_i) and holding costs (h_i) decrease between 10 – 50%.
- *High Costs:* It is a pessimist scenario; the mayor cost (S), minor costs (s_i) and holding costs (h_i) increases between 10 – 50%.
- *Random:* All parameters varies in a range of $\pm 30\%$

The parameters for the current scenario are listed in Table 1, in addition the mayor cost (S) was fixed in 2750 USD, and the transport cost in 3000 USD and the service level in 95%. The shared warehouse space considered for the coalition was 190 cubic meters at petition of the companies. The average transport capacity is 60 cubic meters. The available space in the Table 1 corresponds to the current space rent by the players, which is used for calculating the case where the player does not use de collaborative strategy.

Table 1: Parameters for the current case

Parameter	***P1***	***P2***	***P3***	***P4***
D_i (unit)	1832	1565	861	663
s_i (USD)	1068	219	684	519
h_i (USD/unit)	1,04	1,34	0,55	0,3
w_i (mt^3)	0,06	0,096	0,096	0,06
σ_i	186,3	100,7	192,9	293,7
Available Space (mt^3)	40	45	47	43

The results obtained are presented in Table 1. The values within the table correspond to the percentage savings are obtained the results of the results of acting individually and the proposed method. To calculate the first one, just consider to apply the heuristic of section 5 solving the objective function (5).

Table 2: Summary results of the case study; percentage of savings obtained using the collaborative strategy

Type	**P1**			**P2**			**P3**			**P4**		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Current	[1]DNA	DNA	26.7	DNA	DNA	25.8	DNA	DNA	33.4	DNA	DNA	38.8
Low Demand	13.2	29.1	23.8	17.1	27.1	24.9	20.1	38.2	31.5	41.2	72.2	57.0
High Demand	21.1	34.6	29.8	8.7	22.2	14.9	25.2	39.1	32.8	30.0	47.2	39.8
Low Cost	40.1	54.2	43.6	43.2	62.1	55.7	39.1	55.2	48.9	50.5	80.1	60.8
High Cost	-1.1	15.3	8.8	-2.3	12.4	4.6	18.2	33.2	26.1	12.4	28.2	21.5
Random	17.9	36.2	28.4	12.3	26.8	19.9	24.5	43.2	33.5	26.4	43.2	38.2
General Summary	***-1.1***	***54.2***	***26.9***	**-2.3**	***62.1***	***24.3***	***18.2***	***55.2***	***34.4***	***12.4***	***80.1***	***42.7***

Considering a long term horizon, all scenarios consistently provided potential benefits, at exception of the high cost scenario. In this case, the benefit obtained corresponds to a negative value (-1.1% for player 1 and -2.3% for player 2). It means that there are some coalitions of players in which the increase in benefits is higher than the one obtained when the players 1 and 2 belongs to them. The ordering and holding cost of these players is high compared to players 3 and 4, and their contribution is so low that no benefit can be perceived by including them. In that case players 1 and 2 should not be part of the coalition if always the conditions are non-favorable. However, in the medium and long term all players could gain benefits by being part of the collation since it allows them to take better advantage of favorable market situations, and better adaptation to unfavorable ones as shown the Table 12 in the general summary. The total average cost reduction is of 26.9%, 24.3%, 34.4%, and 42% for players 1, 2, 3 and 4 respectively, considering a time horizon where all scenarios are equally possible.

The results shows that companies with limited capacity and high demand as the player 1 and 2 could achieve a cost reduction by implementing the proposed strategy. These players take advantage of the joint increase of storage capacity and develop less order per period, so they perceive a reduction of their ordering cost. On another hand, the players 3 and 4 have excess capacity and reduce their holding cost by decreasing the cost of warehouse rental. Players 1 and 2 have a higher demand than 3 and 4, but they do not obtain better benefits than 3 and 4. This situation is because the best exploitation of economies of scale is when the 4 players perform a joint replenishment, but the players 3 and 4 are not included in all the replenishments, so players 1 and 2 assume a large portion of fixed costs. For an extension of this last situation consult Otero, Amaya, & Yie-Pinedo (2017).

[1] Does not apply

8. Conclusions

This paper proposes a collaborative strategy where non-competitor companies can share logistical resources and fixed costs related to manage inventories. Trough a study case was demonstrated that a potential cost reduction can be achieved. The model is especially useful for companies with limited resources because it provides the opportunity to achieve increase of capacity and exploitation of economies of scale. On another hand, the strategy allows improving the efficiency of companies with overcapacity thanks to a better use of resources. The tests showed that players with similar conditions; demand and operational costs, can obtain comparable benefits by forming coalitions, but the coalitions formed by player with heterogeneous conditions could be unstable. In these cases, the players who contribute with little charge and large costs can achieve high cost reductions, even more that big players because they take greater advantage of the resource of the first ones, while the latter achieve little benefits. The selection of players and the formation of coalitions should be more widely studied. Future research must consider the possibility of multi objective function; where the main propose is not reduce costs. Another important topic is the accuracy of the space required, since this paper considered that the products are packed in boxes or units of load with regular and standard forms. This assumption can significantly alter the results if there are products with irregular shapes.

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