Unsold inventory management and off-price retailers' selection for multiple items

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Abstract

In this research, we address the issue of outsourcing the clearance operation to a third party, in the context of multi-partner and multi-product. The outsourcing operation is a widespread industrial practice and requires a well-defined process to follow to be successful. Indeed, to choose the best partners (or retailers) from a potential set of candidates, a company must define its selection criteria, as well as the selection method that should be applied. This paper aims to develop a framework for the clearance partner selection process. Using multi-objective optimization and based on the suppliers' evaluation according to the established criteria, appropriate partners are selected, and optimal allocation of unsold quantity is determined.

Keywords
Outsourcing decision, clearance partners, multi-product, multi-partner, multi-objective optimization.

1. Introduction
The excess inventory represents a frequent problem for companies. Indeed, the unsold products quantities in various sectors are significant and should not be underestimated: they exceed 40% in the agri-food industry, about 30% for electronic products and reach 50% in the textile industry. The rates are more important in other areas such as publishing, where the value of surplus stocks is about 60% [Mechmech *et al.,* 2022].

Academics and professionals are continuously trying to propose the best solutions to liquidate remaining products. Mechmech *et al.* (2022) present two main periods relative to the product lifecycle (Figure 1). The first one represents the market period where the company applies a mark-up price policy to sell its new-season items. Remaining products after this period will be called the unsold items and need to be liquidated during the selling-off period. As a first step, company should apply the mark-down policy that is mainly represented by the cash-recovery strategies (Table 1). These strategies are defined as the clearance strategies aiming to liquidate unsold inventory and provide instant cash. Afterwards, the dead stock that is left will be eliminated by the disposal strategies.

According to the same study, several in-house clearance strategies (Table 1) may be used to clear the excess stocks. However, companies will bear different fixed costs due to the strategies implementation process, the management operations, etc. As to the external strategies, they may represent a good way for companies to avoid additional fixed costs and to focus on their core business, namely managing in-season's products. These external strategies involve dealing with partners, that are known as "discounters" and "clearance wholesalers". Their objective is to buy the unsold products and resell them to other markets. The main difference is that discounters operate in BtoC transactions, while the clearance wholesalers focus on BtoB transactions. The most important feature of these partners is that they offer the possibility of disposing of unsold goods in heterogeneous pallets. Thus, the company will be able to liquidate, at once, different types of unsold items relative to several previous seasons. However, their main drawback is the low price offered for purchasing unsold inventory.

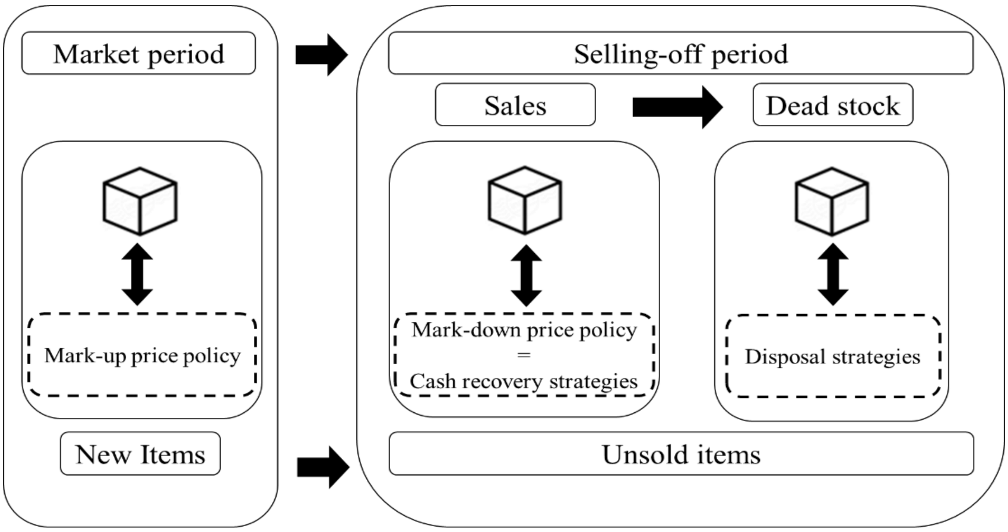

Figure 1: Lifecycle product through the market and selling-off periods [Mechmech *et al.,* 2022]

Table 1: Clearance strategies [Mechmech *et al.,* 2022]

CC Strategies (S_i)	**Classification**	
S1: Clearance sales	Cash-recovery strategies	In-house strategies
S2: Factory outlet		
S3: Online clearance		
S4: Discounters		External strategies
S5: Clearance wholesalers		
S6: Recycling	Disposal strategies	
S7: Destruction		
S8: Donation		

According to Riandita (2022), companies aim to establish partnerships to acquire new skills and capabilities. However, the selection of external partners represents a critical problem in the literature as well as in practice. Indeed, building a new partnership represents a strategic decision that must be efficiently and carefully studied because of its critical long-term consequences. Therefore, the selection of the adequate partners represents the most essential step in this decision-making process. Collaborating with a reliable external partner is considered as the key factor to a successful and sustainable partnership. Mechmech *et al.* (2020) introduce several criteria ensuring the clearance partner selection, also called the "Off-Price retailers". In the present work, a framework for selecting the right partners is developed. Moreover, the mathematical model developed by Mechmech *et al.* (2020) is extended to the multi-product case. Finally, the solution approach will be based on a lexicographic optimization using the CPLEX software.

The remainder of this paper is organized as follows. The second section presents a literature review on the issues of partner selection and order allocation. The third section outlines the proposed framework and solution approach. Section 4 presents an illustrative example and Section 5 discusses the results and concludes the paper.

1.1. Objectives

This paper deals with the externalization of the clearance operation in the multi-product case and aims to:

- Propose the relevant criteria to evaluate external clearance partners.
- Propose a well-defined process to follow to select the appropriate external clearance partners.
- Select the best partners from a pre-defined list (qualitative selection) and allocate unsold inventory based on a mathematical model. The developed model shall use both quantitative selection criteria and subjective clearance evaluation (which represents the managers expectations).

2. Literature review

In this section, we firstly present the relevant literature review related to the external partner selection process. Then, we expose the literature related to the quantity allocation under multiple products. Mainly, this review is based the existing literature related to similar problems such as the supplier selection, since the clearance context is not sufficiently examined (Rogers *et al.,* 2012).

2.1. Partner selection process

According to Miranda-Ackerman *et al.* (2019), the selection process represents the adopted approach or steps to select a new partner. In the academic literature, the different selection processes are presented in between three and seven steps.

The most classical selection process is the one presented by De Boer (1998) (Figure 2). The author introduced an approach stressing that the selection problem involves more decision steps than a simple final choice. According to the proposed framework, the problem generally consists of four phases:

- Problem definition: the company must ask itself the question "Should we actually outsource"?
- The formulation of the selection criteria: the company needs to define the selection criteria that represent its objectives and expectations as well as their relative importance.
- Qualification: the company focuses on the initial/ large set of suppliers, ranks, and evaluates them.
- Final selection: the company chooses the optimal number of suppliers to collaborate with, allocates quantities, specifies the interaction rate, etc.

	New task	***Modified rebuy (leverage items)***	***Straight rebuy (routine items)***	***Straight rebuy (strategic/bottleneck)***
Problem definition	*Use a supplier or not?*	*Use more, fewer or other suppliers?*	*Replacing the current supplier?*	*How to deal with the supplier?*
Formulation of criteria	*Varying importance One-off decision No historical data on suppliers available No previously used criteria available Varying importance*	*Moderate/high importance Repeating decision Historical data on suppliers available Previously used criteria available*	*Low/moderate importance Repeating decision Historical data on suppliers available Previously used criteria available*	*High importance Repeating decision Historical data on suppliers available, yet very few actual selections Previously used criteria available*
Qualification	*Small initial set of suppliers Sorting rather than raking No historical records available*	*Large set of initial suppliers Sorting as well as raking Historical data available*	*Large set of initial suppliers Sorting rather than raking Historical data available*	*Very small set of suppliers Sorting rather than raking Historical data available*
Choice	*Small initial set of suppliers Ranking rather than sorting Many criteria Much interaction No historical records available Varying importance Model used once*	*Small to moderate set of initial suppliers Ranking rather than sorting Also: how to allocate volume? Fewer criteria Less interaction Historical data available Model used again*	*Small to moderate set of initial suppliers Ranking rather than sorting Fewer criteria Less interaction Historical data available Model used again Single sourcing rather than multiple sourcing*	*Very small set of suppliers (often only one) Historical data available Evaluation rather selection Sole sourcing*

Figure 2: Supplier selection process [De Boer (1998)]

Based on the examined literature, Igarashi *et al.* (2015) underline that the supplier selection process is considered as a multi-stage, multi-criteria problem. Based on Cousins *et al*. (2008), De Boer *et al.* (2001) and Morton (2002), Igarashi *et al.* (2015) propose the following six-step selection process (Figure 3):

- Identification of needs and specifications: the features of the outsourcing decision, the number of suppliers, the number of products, etc.
- Formulation of criteria: the criteria that will reflect the company's expectations and suppliers' characterization.
- Call for tenders: a call for tenders is communicated for potential candidates.
- Qualification: purchasers make a preliminary selection after having reviewed the submitted information by the candidate suppliers, which is generally called the qualification phase.
- Final selection: this step presents a short list of the most adequate suppliers which are drawn from the qualification stage.
- Evaluation of supplier performance: it represents the post-selection evaluation (Morton, 2002) step which consists of a continuous review of the chosen supplier's reliability. Based on Figure 3, we underline that this step provides continuous feedback used to improve and enhance the criteria identification, the qualification, and the final selection steps.

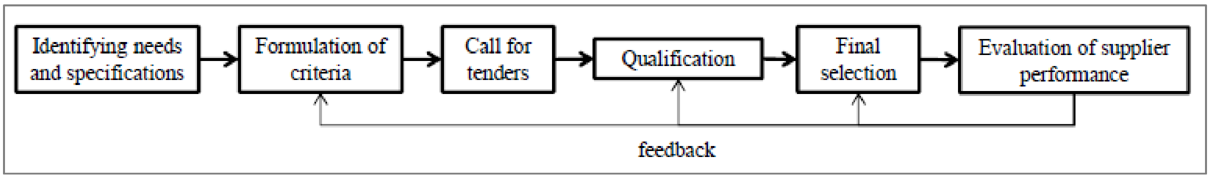

Figure 3 : Supplier selection process [Cousins *et al*., 2008 ; De Boer *et al*., 2001 ; Morton, 2002 ; Igarashi *et al.*, 2015]

Monczka *et al.* (2015) propose a selection process based on seven steps (Figure 4):

- Recognize the need for supplier selection: which represents the need for the outsourcing operation as example for a new item or service.
- Identify key sourcing requirements represents the preliminary specifications required by the external partner for the new purchase, service, etc.
- Determine the sourcing strategy: there is no standard sourcing strategy that can satisfy the requirements of all purchasing activities. Therefore, it is necessary to choose the most appropriate one for the concerned item or service.
- Identify potential supply source: various information is useful in identifying possible supply sources, such as the capacity of the existing suppliers to meet cost, quality, or other performance variables.
- Limit suppliers in selection pool: in this step, the company should limit the initial number of suppliers and choose a short list of the most adequate ones.
- Determine the method of supplier evaluation and selection: the used approach or method to select the best suppliers represents a key feature to the decision success. Indeed, it depends on several factors such as the expected results, the availability of information, etc.
- Select supplier(s) and reach agreement: it represents the final step where the most adequate supplier(s) is/are selected. The next step will focus on the signed agreement and the partnership's longevity.

A three-step process is presented by Wetzstein *et al.* (2016) for the selection of the suitable suppliers. They begin by the:

- Identification of criteria: the company should specify the criteria that reflect its objectives and expectations.
- The determination of ranking methods: at this stage, the company should select the most appropriate approach that ensures the selection of the new partners. The chosen approach must meet the firms' requirements and the data availability.
- Supplier selection: this final step represents the ultimate selection where the most adequate suppliers are chosen based on the pre-defined criteria, company expectations, etc. (Figure 4)

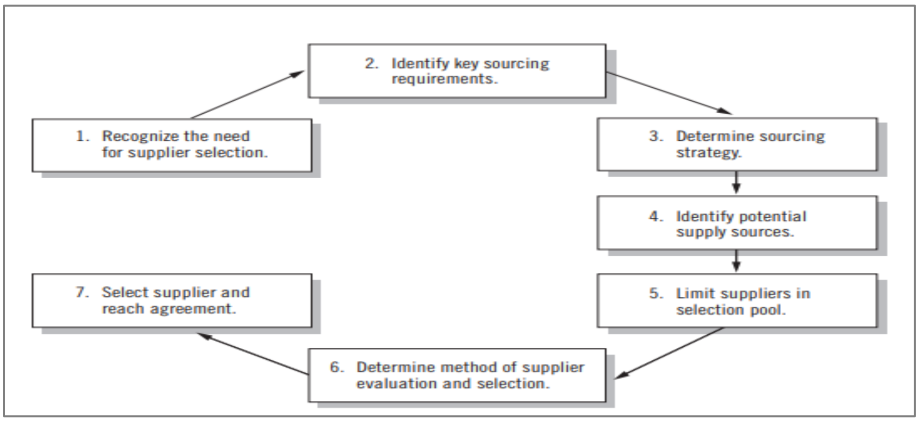

Figure 4: Supplier evaluation and selection process [Monczka *et al.* (2015)]

Miranda-Ackerman *et al.* (2019) focus on the Supplier Selection Process. Their main objective is to select the adequate green supplier in the agri-food industry. They introduce a seven-step selection process as presented in Table 2.

- The first phase establishes a predetermined list of potential suppliers. Then, this list is refined based on decision criteria and predefined objectives by the decision-maker, considering the desirable requirements and expectations.
- The supplier characterization step represents a critical phase. Indeed, it presents the most evaluated characteristics such as the quality, cost and delivery performance.
- The supplier network model step aims to propose the optimal approach to ensure the overall performance of the supply chain while considering the different technologies, constraints (financial, environmental, capacities, etc.), etc.
- The fifth and sixth steps represent the selection decision of the most adequate suppliers based on the proposed approach/model. Finally, a classification and a ranking of the different selected partners are carried out to establish negotiations and collaborations.

Table 2: Selection process proposed by Miranda-Ackerman *et al.* (2019)

No.	Description
1	Pre-selection or scouting of suppliers
2	Short listing based on common sense judgment
3	Supplier characterization
4	Supplier network model
5	Supplier network optimization
6	Supplier network selection
7	Supplier negotiation and contracting

Zhang *et al*. (2020) present a literature review related to the supplier section in the reverse logistic context. They underline three stages in the supplier selection process (Figure 5):

- Establishment of the selection criteria.
- Computation of the relative weights and ranking of the selection criteria.
- Ranking of alternatives (suppliers).

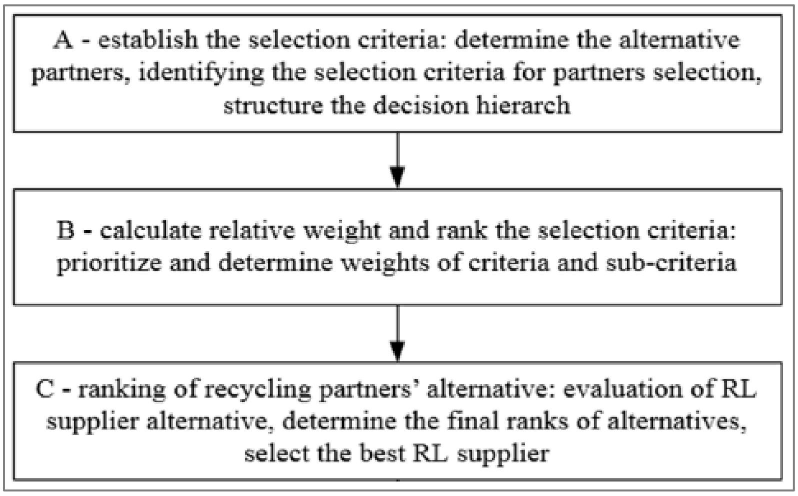

Figure 5: Reverse logistic supplier selection process [Zhang *et al*. (2020)]

2.2.Unsold inventory allocation

The selection of the suitable partners is usually accompanied by the allocation of quantities in the multi-sourcing case, given that a single partner is generally not able to meet all a company's demand. Throughout the academic literature, the allocation of quantities to the different suppliers is generally made using mathematical optimization where the objective function is chosen according to the context. Aouadni *et al.* (2019) present a literature review of 270 papers published between 2000 - 2017 focusing on the supplier selection (and quantity allocation). The authors mention that quantitative methods are commonly used in this research area. According to the same study, the developed models are of two types: single-objective and multi-objective. In the first case, the objective function represents one criterion. Any other issue is taken into consideration as a constraint in the decision model. In the case of a multi-objective model, the model to be optimized has more than one objective function. According to the same study, choosing the most appropriate partners consists of deciding on two main features: (1) whether to use single or multiple sourcing policies when acquiring a particular material resource and (2) the number of items / services considered Scott *et al.* 2015; Turk *et al.* 2017).

The present research focuses on the used approaches when having a multiple sourcing strategy. Therefore, it addresses the "allocation problem". Moreover, it considers the multi-product case (Figure 6) where the company must deal with different unsold products. Figure 6 shows the positioning of the present work compared to existing studies. Although research in this field has widely considered the supplier selection problem, very few addressed the multi-product case (Cárdenas-Barrón *et al.*, 2015; Ayhan and Kilic 2015; Khoshfetrat *et al.* 2020) and much less the selection of partners for managing unsold inventory.

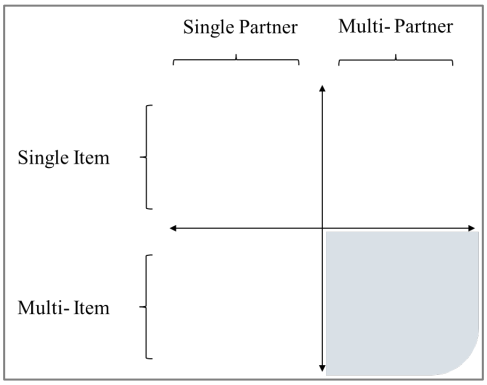

Figure 6: Specifications of the current work

In the unsold inventory management context, we highlight the work of Mechmech *et al.* (2020) where they develop a multi-objective model selecting the best Off-Price retailers. They aim is to maximize the total selling price, the drained volume by each partner comparatively with the flow speed and to minimize the payment delay to the firm. The developed model represents the multi-partner single-item case. Authors use the fuzzy AHP method to obtain a risk-performance evaluation for each clearance partner. This evaluation is used through a mathematical model (as constraints) to ensure a minimum clearance performance level and a maximum tolerated clearance risk level (that should be fixed by managers) in the global selection. The different evaluation features of the risk and performance criteria are presented in Table 3.

Table 3: Evaluation criteria and sub-criteria

	N°	Criteria
Performance (P)	P_1	Clearance network
	P_2	Portfolio of brands
	P_3	Location
	P_4	Packaging/Market
	P_5	Financial position
	P_6	Service quality
Risk (R)	R_1	Reputation
	R_2	Markets portfolio
	R_3	Information sharing

3. Methods (Proposed approach)

In this section, we present the proposed approach which mainly consists in the framework for selecting a set of clearance partners and a mathematical optimization model for allocating unsold inventory of multi-items.

3.1. Framework for Partner Selection

The processes examined in the literature review comprise between three and seven steps to follow. In the present work, we propose a framework based on four main steps, as shown in Figure 7. The first step is to establish a list of potential partners with whom the company could collaborate. The partner searching process is based on the history, surveys, etc. The second step proposes and specifies the relevant criteria. Then, a multi-criteria evaluation and ranking (according to the chosen criteria) will be performed by assigning different weights to the candidates. This step is performed using a multicriteria decision method (MCDM) that should be efficiently selected. Then, a shortlist representing a pre-selection of the best ranked candidates will be established. Based on this list, a multi-criteria decision support model will be developed to designate the most appropriate partners and thus allocate unsold quantities in the case of multi-partners. Steps 1, 2 and 3 constitute the first phase of the process which is based on qualitative criteria. The second phase is the last step of the selection process, which requires specific quantitative data relative to the clearance offer, such as prices, capacities, unsold goods recovery times, etc. Once the information is available, we propose to use a mathematical model to select the appropriate clearance partners and to allocate the quantities of unsold goods.

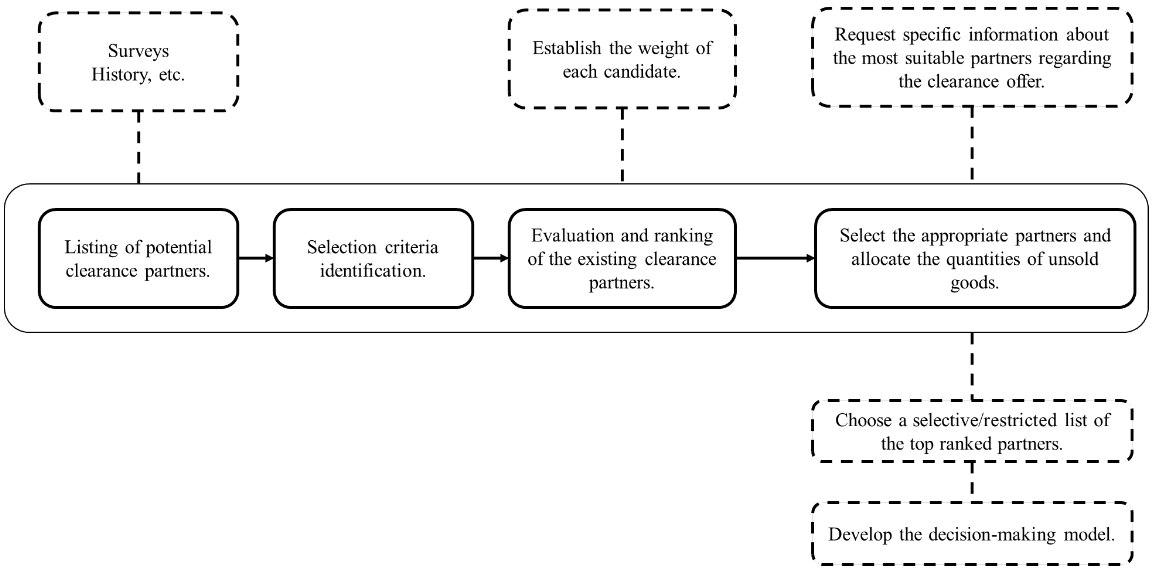

Figure 7: The proposed clearance selection process

3.2. Mathematical model

In this section, we extend the mathematical model proposed by Mechmech *et al.* (2020) to propose the adequate model for the multi Off price Retailers (ORs) multi-product case.

To describe the proposed model, the following notations, parameters, decision variables, objective functions and constraints are introduced:

P : set of products (indexed by j)
N : Number of the chosen ORs for the short list, (indexed by i).
Q_j: unsold quantity of product j.
V_{ij-min}: minimum proposed quantity by the ORs i for product j.
V_{ij-max}: maximum proposed quantity by the ORs i for product j.
P_{ij}: purchasing price proposed by the ORs i for product j.
P_{min}: minimum performance level fixed by the firm.
R_{max}: maximum tolerated risk fixed by the firm.
ORP_i: performance of the OR i mined from the qualitative evaluation step (Mechmech *et al.* 2020).
ORR_i: Risk of the OR i mined from the qualitative evaluation step (Mechmech *et al.* 2020).
L_i: terms of payment of the OR i (per day).
F_i: flow speed proposed by the OR i to release space (per day/ per week or per month).

Decision variables:

X_{ij}: quantity of product j sold to OR i.
Y_i: binary variable to consider the selection of OR i once it is used to liquidate a portion of the unsold product j, that is, $Y_i = 1$ si $X_{ij} > 0$.

Mathematical model:

$$Max \sum_{i=1}^{N} \sum_{j=1}^{P} \left(\frac{X_{ij}}{F_i}\right) \quad (1)$$

$$Max \sum_{i=1}^{N} \sum_{j=1}^{P} (P_{ij} * X_{ij}) \quad (2)$$

$$Min\ [Max\ (L_i * Y_i)]\ , i \in [1..N] \quad (3)$$

S. to

$$\sum_{i=1}^{N} ORR_i * Y_i \leq R_{max} \quad (4)$$

$$\sum_{i=1}^{N} ORP_i * Y_i \geq P_{min} \quad (5)$$

$$\sum_{i=1}^{N} X_{ij} \leq Q_j\ , \forall j \in [1..P] \quad (6)$$

$$V_{ij-min} * Y_i \leq X_{ij} \leq V_{ij-max} * Y_i, \forall i \in [1..N], \forall j \in [1..P] \quad (7)$$

$$Y_i \in \{0,1\} \quad (8)$$

$$X_{ij} \geq 0; \forall i \in [1..N], \forall j \in [1..P] \quad (9)$$

The first objective function (1) aims to maximize the total drained quantity by a partner i relative to the flow speed. The second objective (2) maximizes the total selling price. The third objective (3) minimizes the firm's payment delay. In Mechmech *et al.* (2020), objectives (2) and (3) were introduced as constraints in the model. In the present work, all three objectives are considered according to a lexicographical order. Constraints (4) and (5) ensure that a certain level of risk and partner performance is guaranteed. The values of R_{max} and P_{min} are usually set by managers. Constraint (6) ensures that the sold quantity of a product j (to all partners i) does not exceed its total initial quantity. Constraint (7) guarantees that the quantity in product j assigned to partner i does not exceed its proposed min-max quantities. It also reflects the relationship between X_{ij} and Y_i. Finally, constraints (8) and (9) deal with variable range and restrictions.

4. Illustration

In this section, we present a numerical example to illustrate the usefulness of the proposed model using data from the literature. Our case study considers a manufacturing company having a total of 150 000 unsold units of four different items (or products), as shown on Table 4. The company's management has identified eight potential ORs. The risk performance evaluation of the ORs using the fuzzy AHP method are taken from the work of Mechmech *et al.* (2020). The weights of the main criteria are presented in Table 5, and the ones related to the sub-criteria of the performance and risk are respectively presented in Tables 6 and 7.

Table 4: Unsold quantity of product j.

	P_1	P_2	P_3	P_4
Q_j	32000	18000	65000	35000

Table 5: The fuzzy and risk weights of the main criteria

Criteria	$\widetilde{w}_i$			w_i
R	0.21	0.33	0.63	0.36
P	0.37	0.67	1.1	0.64

Table 6: The performance sub-criteia weights

P_i	P_1	P_2	P_3	P_4	P_5	P_6
w_i	0.22	0.08	0.22	0.04	0.32	0.11

Table 7: The risk sub-criteia weights

R_i	R_1	R_2	R_3
w_i	0.66	0.15	0.19

The evaluation of the eight ORs is presented in Table 8. The first row presents the ORs' performance evaluation, the second one presents the risk evaluation, and the third row presents the global score of each partner based on the risk-performance evaluation and their weight previously presented in Table 5. Based on the obtained results (total score), we underline that a five-partner short-list will be considered. The related data to the ORs are presented in Tables 8, 9, 10 11 and 12. We underline that these data are randomly generated.

Table 8: ORs' evaluation

	OR_1	OR_2	OR_3	OR_4	OR_5	OR_6	OR_7	OR_8
P	0.17	0.12	0.11	0.13	0.08	0.13	0.13	0.16
R	0.07	0.12	0.09	0.08	0.22	0.09	0.07	0.16
S	0.13	0.12	0.10	0.11	0.13	0.12	0.11	0.16

Table 9: Flow speed and terms of payment proposed by the five top OR i.

	OR_8	OR_1	OR_5	OR_2	OR_6
L_i	60	65	45	65	60
F_i	15	10	12	11	13

Table 10: Minimum proposed quantity by the five top ORs i for product j

	P_1	P_2	P_3	P_4
OR_8	9476	0	0	11906
OR_1	0	0	8612	0
OR_5	8379	0	20014	13794
OR_2	9365	5649	24660	17334
OR_6	0	3451	0	13227

Table 11: Maximum proposed quantity by the five top ORs i for product j

	P_1	P_2	P_3	P_4
OR_8	21296	0	0	18404
OR_1	0	0	63143	0
OR_5	25256	0	52419	22554
OR_2	23243	11562	60053	29348
OR_6	0	15459	0	21198

Table 12: Purchasing price proposed by the five top ORs i for product j

$	P_1	P_2	P_3	P_4
OR_8	13	0	0	6
OR_1	0	0	22	0
OR_5	11	0	30	7
OR_2	13	5	24	8
OR_6	0	8	0	8

The model is solved using CPLEX 12.9 software and the function "$StaticLex$". The latter ensures a lexicographic optimization for multi-objective model. In our case, we assume the following decreasing order of objectives importance: First, the total drained quantity relative to the flow speed, then comes the total selling price and finally, the payment delay. Results are presented in Figure 8 where the histogram labeled "(1)" represents solution for "$R_{max} = 0.5$ and $P_{min} = 0.45$" and the histogram labeled "(2)" represents the one for "$R_{max} = 0.4$ and $P_{min} = 0.4$". (Figure 8)

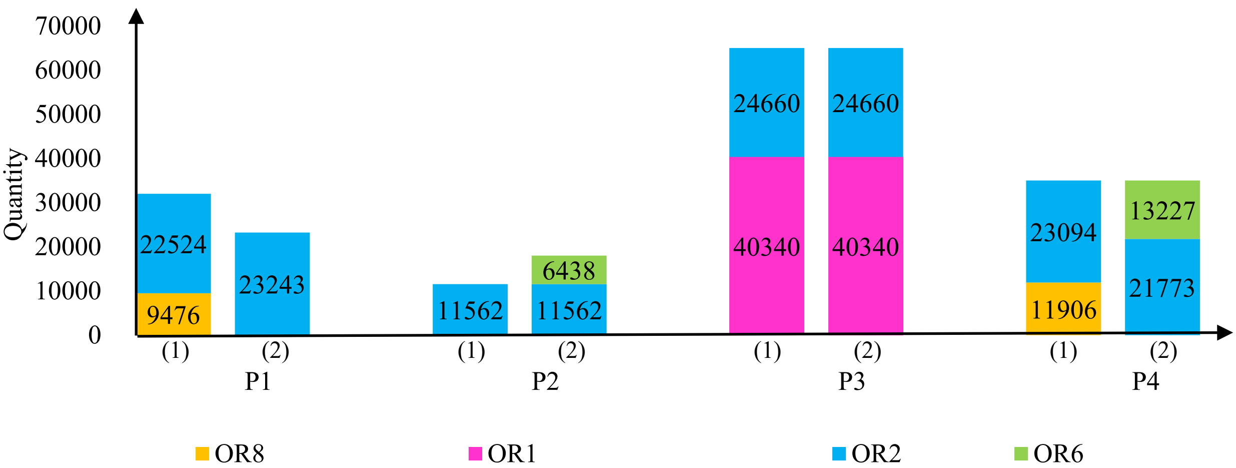

Figure 8: The Selected ORs for each product

4.1.Results and discussion

In both presented cases (Figure 8), only three clearance partners are selected. However, the selected partner, the allocated quantities and the selected products are not the same. In the first case, the selected partners are: OR_8, OR_1 and OR_2. However, in the second one, OR_1, OR_2 and OR_6 are the selected ones. Comparing the two simulations (1) and (2), we point out that the tolerated risk value and the minimum performance one is decreased. Accordingly, we note the substitution of the OR_8 by the OR_6 since the latter has a lower risk value (Table 8).

We emphasize that the optimal decision does not necessarily involve a partner for different types of products: a partner can be selected even for a single product. Although the number of selected partners is the same, the solutions differ in terms of non-allocated quantities and products (Table 13). This is due to the capacity constraints of the partners that are product dependent.

Table 13: Total profit and remaining products for each solution

	Solution 1	Solution 2
Total profit ($)	2209318	2170793
Remaining products:		
• **Product type**	P_2	P_1
• **Quantity (units)**	6438	8757

Our major finding is that the optimal solution differs according to the values of R_{max} and P_{min}. Therefore, their values must be carefully established based on a well-studied benchmark that includes all relevant actors in this decision. We underline that in our case (considering the current numerical values), some values of R_{max} and P_{min} did not even lead to feasible solutions.

5. Conclusion

The selection of the best clearance partners, also called ORs retailers, based on relevant, well-defined, and effective criteria is one of the most crucial decisions that contribute to the success of the clearance chain process. This research presents an extension of the conducted work by Mechmech *et al* (2020) to the multi-item context. A framework for clearance partner selection. Indeed, a four-step decision-making framework is developed, which represents a useful tool for selecting clearance partners. In a second step, an extension of the mathematical model developed by Mechmech *et al* (2020) is proposed. The latter aims to select partners and allocate the unsold inventory for a single product, using the ε-constraint technique. The model of the present work aims to handle the multi-product multi-partner case, while explicitly considering three objective functions. The resolution is carried out with the lexicographic multi-objective optimization using the CPLEX software. Results show that the optimal solution is highly dependent on expert opinions and performance risk evaluations. Similarly, we point out that two solutions differ in terms of total profit and liquidated quantity per product even if they have the same number of selected partners.

In this work, the evaluation of the clearance partners is conducted based on the subjective opinions of managers and subjective MDMC methods. Future work will explore other selection methods that are less subjective.

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