ABC categorization using the ELECTRE TRI method to storage location assignment

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ABSTRACT

Every day increases the importance of an efficient storage location assignment system. Moreover, since the products have different warehouse costs and customers' requirements are also different, it is important to sort products in order to adopt strategies for inventory management appropriate for each product. However, the adoption of a policy for each product is not applicable in the real world. For this fact, companies commonly adopt the ABC categorization to sort products and they adopt specific policies to each class. Observing this, it is proposed to adopt a multi-criteria method, the ELECTRE TRI, for sorting products considering both criteria relating to product characteristics to their physical location in the warehouse and the relevant criteria inventory strategies, such as, for example, the profitability of each storage unit.

Keywords: ABC classification, Location of items in warehouse, Electre TRI method.

RESUMO

A cada dia aumenta-se a importância de um eficiente sistema de atribuição de locais em armazéns. Além disso, uma vez que os produtos têm custos de armazenagem distintos, bem como demandas diferentes, é importante classificar os produtos a fim de adotar estratégias de gestão de estoques adequadas para cada produto. No entanto, a adoção de uma política para cada produto não é aplicável no mundo real. Por este fato, as empresas geralmente adotam a categorização ABC para classificar os produtos e adotar políticas específicas para cada classe. Observando isso, propõe-se neste artigo a adoção de um método multicritério, o ELECTRE TRI, para classificar os produtos considerando tanto os critérios relativos às características do produto para a sua localização física no armazém, como, também, os critérios relevantes ás estratégias de inventário, como por exemplo a rentabilidade de cada unidade estocada.

PALAVARAS CHAVE. Classificação ABC, Localização de itens no armazém, método ELECTRE TRI.

1. Introduction

Storage is one of the more traditional areas of logistics. The store is the core business of companies such as whole sale distributors. A costly way to increase the productivity of storage is through a new distribution center design (layout). It can also increase productivity by less radical methods, including changes in warehousing activities (Chen et al. 2005).

Moreover, the number of stock-keeping units (SKUs) held by larger firms can easily reach tens of thousands. Clearly, it is not economically feasible to design an inventory management policy for each individual SKU (Chen et al. 2008). For this fact, companies commonly adopt the ABC categorization to sort products and they adopt specific policies to each class.

Therefore, the objective of this paper is to use ABC classification as storage location assignment system in warehouse. An allocation determined by the ABC classification can assign items to the correct location warehouse, according preference of decision maker, as serve as categorization for the inventory policies.

For this, it was chosen a multi-criteria outranking method to determine the ABC categorization. This type of method is appropriate due its characteristic of non-compensation between the criteria. It was posed by the decision maker in this study. Through the ELECTRE TRI is possible to assign the allocation into the classes. Moreover, once it is made to insert new products do not need to reclassify the others, because the methods make comparisons as the limits of the classes to sort each item.

This paper is structured as follows. Section 2 presents some important general concepts. The section 3 reports the ABC classification system and ELECTRE TRI method to apply in the warehouse management. An illustrative example is presented in section 4. Next, the results and analysis are showed. Finally, it does the concluding remarks in section 6.

2. Overview

Warehouse storage decisions influence almost all the key performance indicators of a warehouse such as order picking time and cost of storage space used, labor, order picking, etc (Li et al., 2008).

According to Goebel (1996) the proper functioning of the warehouse requires that it develop a system for rapid transfer of cargo from origin of product to its destination, immobilizing the vehicle for the shortest possible time. For Daniels et al (1998), changes in demand and a consequent redistribution of the warehouse spaces often require the movement of stocks that could cause serious disruption in the warehouse operations, especially when the warehouse is often used.

The efficiency of handling operations and storage depends on the degree of planning the layout. In the pursuit of internal efficiency, it is important to examine whether the current layout of the warehouse is not operating as a bottleneck for this, and to verify if the available resources are sufficient for a rapid and efficient logistics operation (Freitas et al. 2006).

However, changes in the layout of a warehouse require a high investment. Measures concerning the choice of more efficient layout should be taken at the time of the warehouse project. Once this has already been designed, other strategies may be taken to behold warehousing activities more efficient. They are, for example, storage location assignment system and order picking system.

2.1. Order picking system

Since warehousing activities are frequent and numerous, even small improvements can achieve significant savings (Chen et al., 2005). Order picking has been considered as the most critical operation in warehousing. Jane and Laih (2005) define the order picking as the process by which the appropriate amounts of products are made from a specific location on the stock to fulfill orders of clients.

The most common objective of order picking systems is to maximize the level of services subject to resource constraints, such as: labor, machinery and capital (Goetschalckx and Ashayeri, 1989 apud Koster et al. 2007).The efficiency of an order picking process greatly depends on the storage policy used, i.e. where products are located within the warehouse (Le-Duc and Koster, 2005).

The selection of a method for order picking is a strategic decision, since it has a broad impact in many other decisions in the warehouse design and operation (Gu et al (2007). Four methods can be used to reduce the distances traveled to order picking the items and consequently the time required for this, following: 1) Determine a route picking; 2) Zoning warehouse, 3) Allocation of batching orders, 4) Assigning items to the correct location warehouse (Muppani and Adil, 2008a).

Petersen and Aase (2004) report that the routes come up with policies to minimize the distance traveled by the picker, and hence the time needed by using simple heuristics or optimal procedures.

Koster et al (2007) presented that the picking area can be divided into zones as an alternative to the single order picking. For each picker is assigned to part of the order that is in their area. Possible advantages of zoning include the fact that each order in the picker must traverse a smaller area, traffic congestion is reduced, and there is the possibility these pickers to familiarize themselves with the locations of items in the zone. The main disadvantage of zoning is that the orders are separate and it must be consolidated again before shipment to the customer.

An order contains all the products and quantities requested by a client or a work of production/assembly – in the case of a distribution center or production warehouse, respectively. When an order contains multiple SKUs, they must be collected and sorted before they are transported to the shipping area or the flow of production (Van Den Berg and Zijm, 1999).

Thus, batch is a set of orders that are grouped to be selected together in one trip (picking). For this approach, orders must be consolidated before picking operations (Chen and Wu, 2005). The main decision involved in order batching is as a particular set of customer orders should be combined so that the total length of all trip needed to pick all the items is minimized (Henn et al. 2010).

2.2. Storage location assignment system

According Gu et al. (2007) different storage strategies can be used. The selection of which storage strategy to use is considered a design problem. However, the implementation of each storage strategy is an operational issue. Three categories to storage location assignment system are presented by Hausman et al. (1976 apud Li et al. 2008), which are: fixed or dedicated storage, random or variable storage, and class-based storage.

A dedicated storage policy prescribes a particular location for the storage of each product (Rouwenhorst et al. 2000), such that no other item can be stored there, even if the space is empty. Under a dedicated storage policy each storage area may only be used for a specific item. The materials are placed in existing open spaces. A randomized storage policy allows items to be stored anywhere in the storage area. Randomized and dedicated storage are extreme cases of class-based storage policy: randomized storage considers a single class and dedicated storage considers one class for each item (Muppani and Adil 2008a).

For the formation of classes Hesket, in1963, proposed the cube-per-order index (COI). This captures the popularity of the item and its condition of storage space, which is expressed as the ratio of storage space required (cube) per SKU and the order frequency of the SKU (Brynzér and Johansson, 1996). The rule ranks the items in ascending order of the index, and then it assigns them in that order to the locations nearest to the I/O (Input / Output) point, in order to reduce the cost of order picking (Jane and Laih 2005).

According Goetschalckx and Ratliff (1990 apud Muppani and Adil 2008a) items allocation based on COI values gives optimal allocation in terms of order picking/storing time under dedicated storage policy for single command transaction.

Hackman and Rosenblatt (1990 apud Van Den Berg et al. 1998) were the first to present a model which simultaneously considers both assignment (which products) and allocation (what amounts). They describe a heuristic that attempts to minimize the total costs for picking and replenishing.

Brynzér and Johansson (1996) describe a strategy to pre-structure components (items) through the structures of the products processed in the problems of Stock Location Assignment Problem - SLAP. For Leung and Wang (2000 apud Li et al. 2008) the problem of storage location assignment is a multi-objective optimization (MOP), as it tries to location assignment using goals that may be conflicting. Hsieh and Tsai (2001) presented a 'Bill Of Material' (BOM) oriented to method for stock location assigning by class-based to an system AS / RS.

A model of order picking with a general storage location assignment in a rectangular warehouse system is presented by Chew and Tang (1999). This paper presents the exact probability density function that characterizes the tour of an order picker. Petersen and Aase (2004) analyze the effect of three decisions of the storage process (picking, routing and allocation of items) in order picker travel, which is a major cost in executing a customer order. The authors use a simulation model and sensitivity analysis.

Daniels et al (1998) formulated a heuristic model for simultaneous determination of decisions about storage location assignment and order picking sequencing, and compare it with previous models of order picking. That same year, a genetic algorithm it was proposed, with Pareto optimization and technical niche, for storage location assignment to optimize the storage space required and the efficiency of order picking in an automated warehouse by Li et al (2008).

Muppani and Adil in 2008 (a) used the simulation annealing and (b) the models integer programming (Branch and Bound) to randomly distribute the products within the class-based. They used the COI index to determine these class-based. They compare their results with the dynamic programming algorithm proposed by Van Der Berg (1996).

Fontana and Cavalcante (2010) based on COI index methodology they proposed two new indices, with the general objective to examine the impact of using the number of customers in the storage location assignment in terms of space usage and order picking. The first index is the cube-per-consumer (CIC) which is the ratio of space required by the number of customers, and the second index is the cube-per-order and consumer (COIC) which is the ratio of space required by the order frequency multiplied by the number of customers. While Meghelli-Gaouar and Sari (2010) present the results of a comparative study carried out by simulation. It includes a class-based storage, a purely random storage and storage for heuristic.

By this standard, the purpose of the paper focuses on the use of ABC categorization to location assignment to items in store.

3. ABC classification system

Inventory classification using ABC analysis is one of the most widely employed techniques in organizations. This classification is based on the Pareto principle (Ramanathan, 2006). ABC classification allows organizations to separate stock keeping units (SKUs) into three classes: A – very important; B – moderately important; and C – least important. The amount of time, effort, money and other resources spent on inventory planning and control should be in the relative importance of each item. Thus, the purpose of sorting items into groups is to establish appropriate levels of control over each item (Chu et al. 2008).

In addition, the relatively small number of items at the top of the list (approx. 10%) controlling the majority of the total annual dollar usage constitute class A, and the majority of the items at the bottom of the list (approx. 60%) controlling a relatively small portion of the total annual dollar usage constitute class C. Items between the two classes constitute class B (approx. 30%) (Partovi and Anandarajan 2002). However, the method can easily be extended to more classes, simply by dividing the ranked SKUs into more groups (Syntetos et al. 2009).

ABC analysis is simple-to-understand and easy-to-use. However, traditional ABC analysis is based on only single criterion, such as annual dollar usage. It has been recognized that other criteria, such as inventory cost, part criticality, lead time, commonality, obsolescence, substitutability, number of request per year, scarcity, durability, reparability, order size requirement, stock-ability, demand distribution and stock-out penalty, are also important in inventory classification (Ng 2007). The multi-criteria classifications allow greater flexibility in adjusting service targets, by category, in order to achieve overall targets at minimum cost (Syntetos et al. 2009).

In general, papers using ABC classification for inventory, they aim to adopt a policy storage specifies and an adequate level of service for each category. However, the objective of this paper is to adopt the ABC classification to determine of classes of items and storage location assignment of these.

Previously, it was said that, in the literature, the COI index is used to determine the class-based storage. However, this calculation requires that they be made all possible combinations of classes between the products to determine the final categorization. Besides the computational difficulties, when it is insert a new product, all the combinations of products in the class-based storage must be redone to determine a new allocation policy. Moreover, the COI index considers only two criteria in evaluation, namely: space required by the item and its order frequency.

To sum up, using the ABC classification system, this paper intended to determine a category for each item, it regardless of the inclusion of new products, and also it can to consider other criteria such as product profitability. An allocation determined by the ABC besides reaching to a class-based allocation optimal, according to the preferences of the decision maker, it can serve as a sort of storage policies for the company. To this end, this paper chose a Multi-criteria outranking method, ELECTRE TRI, to determine this categorization.

3.1. ELECTRE TRI method

According Figueira et al. (2005), a set of categories must be a priori defined in the sorting problematic. The definition of a category is based on the fact that all potential actions which are assigned to it will be considered further in the same way. In sorting problematic, each action is considered independently from the others in order to determine the categories to which it seems justified to assign it, by means of comparisons to profiles (bounds, limits), norms or references. The sorting problematic refers to absolute judgments. It consists of assigning each action to one of the pre-defined categories which are defined by norms or typical elements of the categories. The assignment of an action *a* to a specific category does not influence the category, to which another action *b* should be assigned.

Therefore, the ELECTRE TRI method is designed to assign a set of actions, objects or items to categories. The categories are ordered; let us assume from the worst (C_1) to the best (C_k). Each category must be characterized by a lower and an upper profile. Let $C = \{C_1, \ldots ,C_h, \ldots ,C_k\}$ denote the set of categories (Figueira et al. 2005), as showed by fig.1.

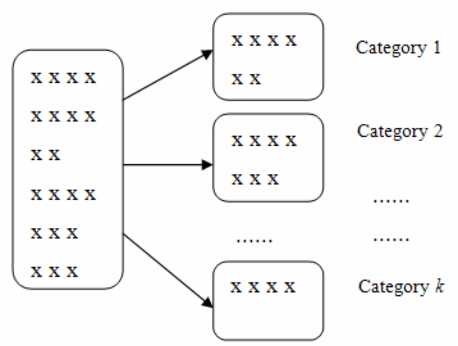

Fig.1. Sorting Problematic - categories ordered
Adapted from Mousseau and Slowinski (1998)

The assignment of a given action *a* to a certain category C_h results from the comparison of *a* to the profiles defining the lower and upper limits of the categories; b_h being the upper limit of category C_h and the lower limit of categoryC_{h+1}, for all $h = 1, \ldots, k$(see fig 2). For a given category limit, b_h, this comparison rely on the credibility of the assertions aSb_h and b_hSa (Figueira et al. 2005).

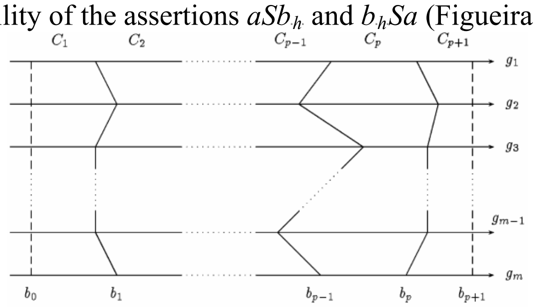

Fig. 2.Definition of categories using limit profiles.
Adapted from Mousseauet al. (2000).

In what follows, it will assume, without any loss of generality that preferences increase with the value on each criterion. After determining the credibility index (σ), it should introduce a λ- cutting level of the fuzzy relation in order to obtain a crisp outranking relation. This level can be defined as the credibility index smallest value compatible with the assertion aSb_h (Figueira et al. 2005).According Mousseau and Slowinski (1998), determining $\sigma(a, b_h)$ consists of the following steps (the value of $\sigma(b_h ,a)$ is computed analogously:

1. Compute the partial concordance index $c_j(a, b_h)$, $\forall j \in F$:

$$c_j(a, b_h) = \begin{cases} 0 \rightarrow if & g_j(b_h) - g_j(a) \geq p_j(b_h) \\ 1 \rightarrow if & g_j(b_h) - g_j(a) \leq q_j(b_h) \\ \dfrac{p_j(b_h) + g_j(a) - g_j(b_h)}{p_j(b_h) - q_j(b_h)} & caso \quad contrário \end{cases} \tag{1}$$

2. Compute the comprehensive concordance index $c_j(a, b_h)$:

$$c(a, b_h) = \frac{\sum_{j \in F} k_j c_j(a, b_h)}{\sum_{j \in F} k_j} \tag{2}$$

3. Compute the discordance indices $d_j(a, b_h)$, $\forall j \in F$:

$$d_j(a, b_h) = \begin{cases} 0 \rightarrow \text{if} \quad g_j(b_h) - g_j(a) \leq p_j(b_h) \\ 1 \rightarrow \text{if} \quad g_j(b_h) - g_j(a) > v_j(b_h) \\ \dfrac{g_j(b_h) + g_j(a) - p_j(b_h)}{v_j(b_h) - p_j(b_h)} \quad \text{caso} \quad \text{contrário} \end{cases} \tag{3}$$

4. Compute the credibility index $\sigma(a, b_h)$ of the outranking relation:

$$\sigma(a, b_h) = c(a, b_h). \prod_{j \in \bar{F}} \frac{1 - d_j(a, b_h)}{1 - c(a, b_h)} \tag{4}$$

where, $\bar{F} = \{j \in F : d_j(a, b_h) > c(a, b_h)\}$.

The values of $\sigma(a, b_h)$, $\sigma(b_h, a)$) and λ determine the preference situation between a aand b_h:

a) $\sigma(a, b_h) \geq \lambda$ and $\sigma(b_h, a) \geq \lambda \rightarrow aSb_h$ and $b_hSa \rightarrow aIb_h$, i. e., a is indifferent to b_h;

b) $\sigma(a, b_h) \geq \lambda$ and $\sigma(b_h, a) < \lambda \rightarrow aSb_h$ and not$b_hSa \rightarrow a \succ b_h$, i. e., a is preferred to b_h (weakly or strongly);

c) $\sigma(a, b_h) < \lambda$ and $\sigma(b_h, a) \geq \lambda \rightarrow$ not aSb_h and $b_hSa \rightarrow b_h \succ a$, i. e., b_h is preferred to a (weakly or strongly);

d) $\sigma(a, b_h) < \lambda$ and $\sigma(b_h, a) < \lambda \rightarrow$ not aSb_h and not $b_hSa \rightarrow aRb_h$, i. e., a is incomparable to b_h.

Figueira et al. (2005) reported that the objective of the exploitation procedure is to exploit the above binary relations. The role of this exploitation is to propose an assignment. This assignment can be grounded on two well-known logics.

1. The conjunctive logic in which an action can be assigned to a category when its evaluation on each criterion is at least as good as the lower limit which has been defined on the criterion to be in this category. The action is hence assigned to the highest category fulfilling this condition.
2. The disjunctive logic in which an action can be assigned to a category, if it has, on at least one criterion, an evaluation at least as good as the lower limit which has been defined on the criterion to be in this category. The action is hence assigned to the highest category fulfilling this condition.

With this disjunctive rule, the assignment of an action is generally higher than with the conjunctive rule. This is why the conjunctive rule is usually interpreted as pessimistic while the disjunctive rule is interpreted as optimistic. This interpretation (optimistic-pessimistic) can be permuted according to the semantic attached to the outranking relation. When no incomparability occurs in the comparison of an action a to the limits of categories, a is assigned to the same category by both the optimistic and the pessimistic procedures. When a is assigned to different categories by the optimistic and pessimistic rules, a is incomparable to all "intermediate" limits within the highest and lowest assignment categories.

The two procedures can be stated as follows,

1. *Pessimistic rule.* An action a will be assigned to the highest category C_h such that aSb_{h-1}.
   a) Compare a successively with b_r, r = $k-1$, $k-2$, . . . , 0.

b) The limit b_h is the first encountered profile such that aSb_h.Assign$a$tocategoryC_{h+1}.

2. *Optimistic rule.* An action a will be assigned to the lowest category C_h such that $b_h \succ$ a.

a) Compare a successively with b_r, $r = 1, 2, \ldots, k - 1$.

b) The limit b_h is the first encountered profile such that $b_h \succ a$. Assign a to category C_h.

However, one of the main difficulties that an analyst must face when interacting with a decisor-maker (DM) in order to build a decision aid procedure is the elicitation of various parameters of the DM's preference model.

Mousseau and Slowinski (1998) report that an ELECTRE TRI model M_π is composed of:

- ✓ The profiles defined by their evaluations $g_j(b_h)$; $\forall j \in F, \forall h \in B$,
- ✓ The importance coefficients k_j , $\forall j \in F$,
- ✓ The indifference and preference thresholds $q_j(b_h)$, $p_j(b_h)$, $\forall j \in F, \forall h \in B$,
- ✓ The veto thresholds $v_j(b_h)$, $\forall j \in F, \forall h \in B$,
- ✓ A selected assignment procedure (either pessimistic or optimistic).

In the ELECTRE TRI method, the analyst should assign values to profiles, weights and thresholds. Even if these parameters can be interpreted, it is difficult to fix directly their values and to have a clear global understanding of the implications of these values in terms of the output of the model. Mousseau et al. (2000) presented a general scheme to inferring these parameters by DM (fig 3).

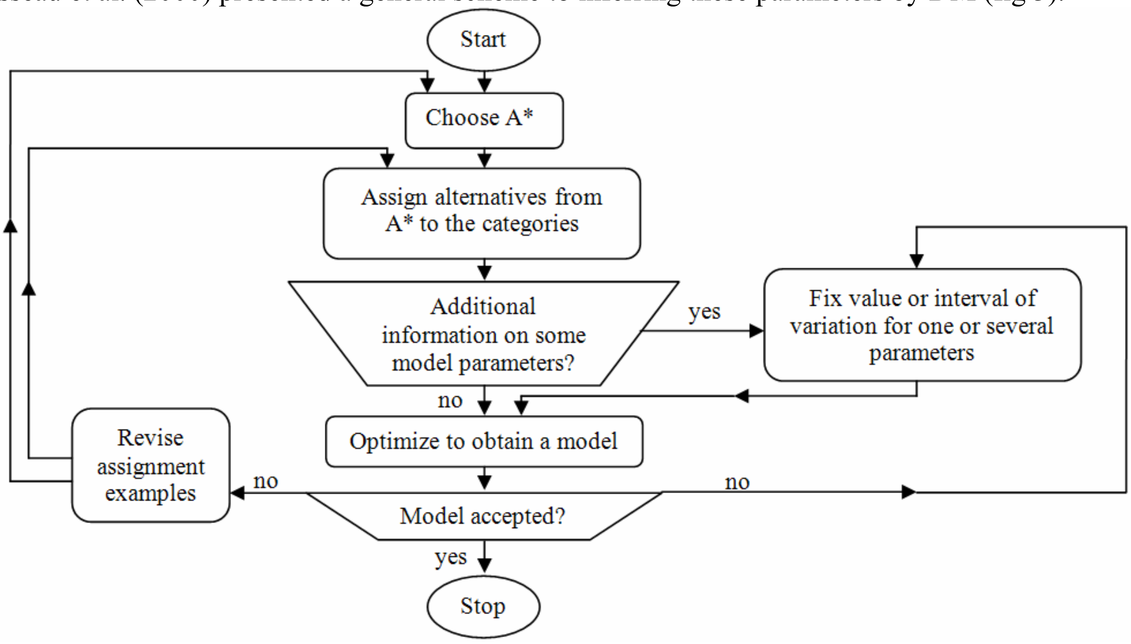

Fig. 3. General scheme of the use of ELECTRE TRI Assistant
Adapted from Mousseau et al. (2000).

Following in the steps (fig. 3) is possible to infer the parameters necessary to apply the ELECTRE TRI method. For more information about this inference of the parameters see Mousseau et al. (2000).

Through the ELECTRE TRI is possible to determine the class-based, and when entering a new products, the method classifies without switching the existing classification of the other products, since the method makes comparisons between the profiles and the alternatives, not between pairs of alternatives.

The illustrative example presented in the sequence was calculated with the help of software ELECTRE TRI 2.0a.

4. Illustrative example

It is considered that the DM has full understanding of the procedure adopted, being able to evaluate all necessary parameters. In this example, the DM aims to subdivide the space available for storage in three areas (A, B and C). Thus in the area around I/O is allocated preferentially to products of low-dimensional, high demand, high profitability and high sensitivity to the level of customer service. With this, the DM wants to increase operational efficiency in those products with higher profitability, greater sensitivity to customers, and also reduce the distances traveled for order picking, since the products of greatest demand and consequently a greater need for order picking are located closer to I/O. Furthermore, as bibliographic data consulted, when the DM finds the products of smaller closer to the I/O they can decrease the average distance traveled in the warehouse to order picking. The warehouse simulated is rectangular, as per Fig. 4.

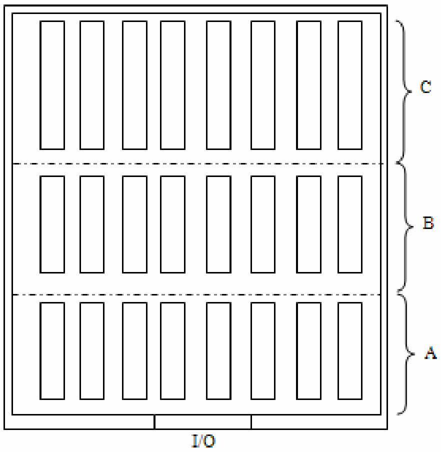

Fig. 4 - Illustration of the layout of the storage area in the warehouse

Within each class of storage products are allocated randomly. Note: the number of class-based storage is determined by the DM.

4.1. Evaluating criteria

The criteria considered are independent, since the DM's preference on a criterion does not change with changes in the values of other criteria. The criteria selected to determine the best alternative for the formation of class and locations in the warehouse are:

- ✓ Size: it is related with the density of the products. It is in the range between 0 and 1 m^2/unit.
- ✓ Demand: it is the order frequency average by clients in each product. The values are between 0 and 1000 units.
- ✓ Profitability: it is the financial return for each unit of product in percentage (%). The values are between 0 and 100 %.
- ✓ Consumer's sensitivity: concerns about a client's particular product may be sensitive to the level of service, for example, the slow delivery of your order. In this criterion the products are evaluated by means of linguistic variables, which are: much, medium, regular, little, very little. To allow for the treatment of this alternative, it is performed the cardinalization assessments, as follows: (4) much, (3) medium, (2) regular, (1) little (0) very little.

4.2. Alternatives and parameters

The simulated warehouse has fifty distinct products (alternatives). To apply the method ELECTRE TRI the values of the alternatives, on all criteria, need to be echelon on a scale between 0 and 100, where 0 means the worst alternative for that criterion and 100 the best alternative on the same criterion. Thus all the alternative criteria aim further evaluation. Table 1 presents a matrix evaluation criteria vs. alternatives, with their values have escalated.

Table 1. Matrix evaluation: Criteria vs. Alternatives

Items	**Demand**	**Size**	**Profit**	**Sensitivity**	**Items**	**Demand**	**Size**	**Profit**	**Sensitivity**
a1	5	94	70	100	a16	68	97	15	100

a2	68	99	33	25	a17	19	89	53	50
a3	26	98	19	75	a18	79	97	76	75
a4	35	99	100	100	a19	8	71	63	75
5a	12	95	10	75	a20	70	97	54	100
a6	56	99	55	0	a21	86	97	20	50
a7	95	99	68	100	a22	98	97	2	100
a8	80	99	20	0	a23	42	93	47	0
a9	45	97	90	75	a24	13	77	30	75
a10	54	98	25	25	a25	6	48	95	0
a11	10	87	5	50	a26	67	95	100	50
a12	23	94	80	25	a27	26	85	41	25
a13	6	72	75	50	a28	73	95	30	75
a14	90	98	30	0	a29	59	92	65	100
a15	4	49	76	25	a30	6	23	15	100

Table 1. Matrix evaluation: Criteria vs. Alternatives (continued)

a31	42	88	85	50	a41	37	82	10	100
a32	32	84	25	50	a42	92	92	5	0
a33	28	81	86	25	a43	9	18	26	50
a34	55	90	15	75	a44	65	88	45	75
a35	35	84	92	0	a45	23	64	53	50
a36	84	93	34	25	a46	73	88	60	100
a37	71	91	4	25	a47	81	90	21	100
a38	29	79	100	100	a48	97	91	46	50
a39	38	83	65	75	a49	10	2	92	25
a40	13	50	50	50	a50	15	33	32	25

The values in Table 1 are relative to the average of the period analyzed. It emphasize that in the Electre TRI the insertion of a new alternative will not change the evaluation of the other, since they are within the ranges defined for each criterion. This point is appropriate considering that most stores do not have a static portfolio of products, and it may, in some cases, oscillate with high frequency.

To infer the parameters, the DM established as the indifference threshold q = 1, preferably threshold p = 2 and a cutting level $\lambda = 0.76$ for all criteria. The inferred profiles and weights can be seen in table 2. As alternatives, the values of the profiles should be scaled between 0 and 100.

Table 2. Profiles and weights

Parameters	**Demand**	**Size**	**Profit**	**Sensitivity**
b_1	60	80	50	50
b_2	40	60	30	25
k	2	1	1	4

The profiles b_1 and b_2 are the limits between classes A and B (b_1) and B and C (b_2).

5. Results and analysis

In this procedure, each alternative was compared to the profiles of the classes. The result of the optimistic and pessimistic version of ELECTRE TRI method can be seen in Table 3.

Table 3. Result of the proposed problem

Items	**Pessimistic assignment**	**Optimistic assignment**	**Items**	**Pessimistic assignment**	**Optimistic assignment**	**Items**	**Pessimistic assignment**	**Optimistic assignment**
a1	C	A	a18	A	A	a35	C	A
a2	B	A	a19	C	A	a36	B	A
a3	C	A	a20	A	A	a37	B	A
a4	C	A	a21	A	A	a38	C	A
a5	C	A	a22	B	A	a39	B	A
a6	C	A	a23	C	B	a40	C	B
a7	A	A	a24	C	A	a41	C	A
a8	C	A	a25	C	A	a42	C	A
a9	B	A	a26	A	A	a43	C	B
a10	B	B	a27	C	B	a44	A	A

a11	C	B	a28	A	A	a45	C	B
a12	C	A	a29	A	A	a46	A	A
a13	C	B	a30	C	A	a47	A	A
a14	C	A	a31	B	A	a48	A	A
a15	C	B	a32	C	B	a49	C	A
a16	B	A	a33	C	A	a50	C	C
a17	C	A	a34	B	A	--	--	--

Figure 5 shows the visualization of the generated classes in the problem by ELECTRE TRI in both assignments (pessimistic and optimistic).

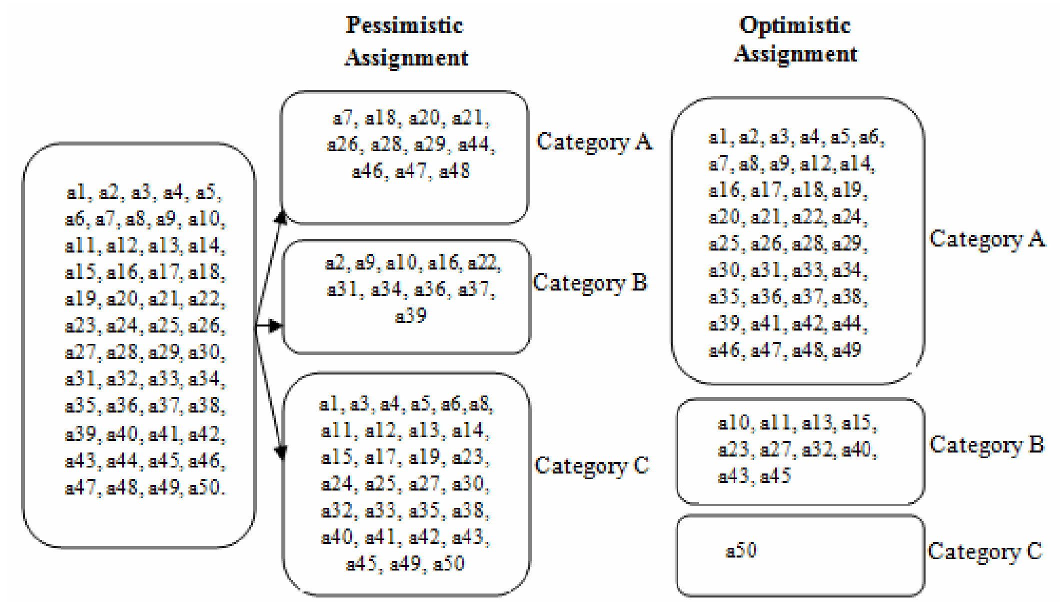

Fig. 5. Illustration of the classification

According to the literature, the optimistic version of ELECTRE TRI is not the most recommended, as this version overestimates the alternatives. In the illustrative example, the products are very divergent in their assessment of each criterion, with very good alternatives in some criteria and very bad in others. By applying the method, the optimistic version located most of the alternatives in category A, while the pessimistic version of the category C. However, the optimistic version does not make much sense to think about strategies for inventory management, therefore, in category A is intended to allocate the products will receive greater attention, which consequently leads to higher operating costs. For this fact, the pessimistic version seems more appropriate the proposed problem.

However, it should be emphasized the importance of examining carefully the categories generated, and mainly, to infer the parameters so that really represent the preferences of the decision maker, to which alternatives very relevant are not subdued and others alternatives less relevant are not overrated.

6. Concluding remarks

This study began with the goal of using a multi-criteria sorting model in the evaluation the characteristics of each product in storage. With this is possible to location assignment of items in a specific area for a class-based storage and, also, sort the products according to the curve ABC and adopt strategies of inventory management appropriate to each class.

For this, the ELECTRE TRI outranking method was chosen due its characteristic of non-compensation between the criteria and because the method allow insertion and/or removal of alternatives without this change to measure the others. The number of classes depends on the objectives and availability of DM. However, for the use of ELECTRE TRI is indispensable this preliminary information, and some parameters previously reported. Therefore, the DM needs to know the procedures adopted to make possible the inference of these parameters.

The ELECTRE TRI method provides two types of sorting problematic, called the assignment optimistic and assignment pessimistic. Despite the pessimistic version be considered more efficient, it is suggested that the adoption of this methodology in stores is accompanied by a survey of operating costs, so that it is possible to weigh the criteria consistently and to reach a solution where it is possible to achieve lower total costs. In the proposed idea is not intended to categorization of lower cost, but one that can optimize the location assignment of the items stocked, at the same time streamline the process of managing inventories.

To sum up, the method ELECTRE TRI to sorting the products in stock is pertinent to consider criteria such distinguished as objective criteria and relating to products (e.g. size of items) and subjective criteria to clients (e.g. the sensitivity of customer service level).

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References

Brynzér, H. and Johansson, M.I. (1996).Storage location assignment: Using the product structure to reduce order picking times. *Int. J. Production Economics*, vol. 46, pp. 595-603.

Chew, E. P. and Tang, L. C. (1999). Travel time analysis for general item location assignment in a rectangular warehouse. *European Journal of Operational Research*, vol. 112, pp. 582-597.

Chen, M.; Huang, C.; Chen, K.; Wu, H. (2005).Aggregation of orders in distribution centers using data mining. *Expert Systems with Applications*, vol. 28, pp. 453-460.

Chen, Y., Li, K.W., Kilgour, D.M. and Hipel, K.W. (2008), A case-based distance model for multiple criteria ABC analysis, Computers & Operations Research, vol. 35 (3), pp. 776-96.

Chen, M. and Wu, H. (2005).An association-based clustering approach to order batching considering customer demand patterns.*Omega - International Journal Of Management Science*, vol. 33, pp. 333-343.

Chu, C-W; Liang, G-S; Liao, C-T. (2008). Controlling inventory by combining ABC analysis and fuzzy classification. Computers & Industrial Engineering, vol. 55, pp. 841–851.

Daniels, R. L.; Rummel, J. L.; Schantz, R. (1998).Model for warehouse order picking.*European Journal of Operational Research*, vol. 115, pp. 1-17.

Figueira, J.; Mousseau, V.; and Roy, B. (2005).Chapter 4.ELECTRE METHODS. In: Multiple criteria decision analysis: state of the art surveys. *International Series in Operations Research & ManagementScience*, vol. 78, n.3, pp. 133-153.

Fontana, M. E. and Cavalcante, C. A. V. (2010).Utilização do número de clientes para formação de classe e localização dos itens para minimização da distância percorrida para *picking*. . *Encontro Nacional de Engenharia de Produção-ENEGEP*.São Carlos, Bazil.

Freitas, F. F. T. de; Nascimento, K. S. C. do; Pelaes, T. S.; França, V. de O. (2006). Otimização das operações de Movimentação e Armazenagem de materiais através de rearranjo físico: uma proposta de melhoria para um almoxarifado da esfera pública. XXVI ENEGEP, Fortaleza, Bazil.

Goebel, D. (1996). Logística – otimização do transporte e estoques na empresa. *Estudos em Comércio Exterior, ECEX/IE/UFRJ*, Rio de Janeiro, vol. 1, n.1.

Gu, J.; Goetschalckx, M.; Mcginnis, L. F. (2007). Research on warehouse operation: A comprehensive review. *European Journal of Operational Research*, vol. 177, pp. 1-21.

Henn, S.; Koch, S.; Doerner, K. F.; Strauss, C.; Wäscher, G. (2010). Metaheuristics for the order batching problem in manual order picking systems. *Business Research*, vol. 3, n. 1, pp. 82-105.

Hsieh, S. and Tsai, K.-C. (2001). A BOM Oriented Class-Based Storage Assignment in an Automated Storage/Retrieval System. *Int J AdvManufTechnol*, vol. 17, pp. 683–691.

Jane, C. andLaih, Y. (2005).A clustering algorithm for item assignment in a synchronized zone order picking system.*European Journal of Operational Research*, vol. 155, pp. 489-496.

Koster, R. de; Le-Duc, T.; Roodbergen, K. J. (2007).Design and control of warehouse order picking: a literature review. *European Journal of Operational Research*, vol. 182, pp. 481–501.

Le-Duc, T., Koster, R. B. M. (M.) de. (2005). Travel distance estimation and storage zone optimization in a 2-block class-based storage strategy warehouse. International Journal of Production Research, vol. 43, pp. 3561 – 3581.

Li, M.; Chen, X.; Liu, C. (2008).Pareto and niche genetic algorithm for storage location assignment optimization problem.*The 3rd International Conference on Innovative Computing Information and Control–IEE*.

Meghelli-Gaouar, N. & Sari, Z. (2010). Assessment of performance of a class-based storage in a flow-rack AS/RS. *Journal of Studies on Manufacturing*, vol. 1, pp. 100-107.

Mousseau, V. and Slowinski, R. (1998).Inferring an ELECTRE TRI Model from Assignment Examples. Journal of Global Optimization, vol. 12, pp. 157–174.

Mousseau, V.; Slowinski, R.; Zielniewicz, P. (2000).A user-oriented implementation of the ELECTRE-TRI method integrating preference elicitation support. Computers & Operations Research, 27, 757-777.

Muppani, V. R. andAdil, G. K. (2008 a).Efficient formation of storage classes forwarehouse storage location assignment: A simulated annealing approach. *International Journal of Management Science*, vol. 36, pp. 609-618.

Muppani, V. R. andAdil, G. K. (2008 b).A branch and bound algorithm for class based storage location assignment. *European Journal of Operational Research*, vol. 189, pp. 492–507.

Ng, W. L. (2007).A simple classifier for multiple criteria ABC analysis. European Journal of Operational Research, vol. 177, pp. 344–353.

Petersen, C. G. andAase, G. (2004).A comparison of picking, storage, and routing policies in manual order picking.*International Journal of Production Economics*, vol. 92, pp. 11-19.

Partovi, F. Y. and Anandarajan, M. (2002).Classifying inventory using an artificial neural network approach. Computers & Industrial Engeneering, vol. 41, pp. 389-404.

Ramanathan, R. (2006). ABC inventory classification with multiple-criteria using weighted linear optimization. Computers & Operations Research, vol. 33, pp. 695–700.

Rouwenhorst, B.; Reuter, B.; Stockrahm, V.; Van Houtum, G. J.; Mantel, R. J.; Zijm, W. H. M. (2000). Warehouse design and control: Framework and literature review. *European Journal of Operational Research*, vol. 122, pp. 515-533.

Syntetos, A. A.; Keyes, M.; Babai, M.Z. (2009). Demand categorisation in a European spare parts logistics network. International Journal of Operations & Production Management, vol. 29, n. 3, pp. 292-316.

Van Den Berg, J. P.; Sharp, G. P.; Gademann, A. J. R. M.; Pochet, Y. (1998). Forward-reserve allocation in a warehouse with unit-load replenishments.*European Journal of Operational Research*, vol. 111, pp. 98-l13.

Van Den Berg, J.P. andZijm, W. H. M. (1999).Models for warehouse management: Classification and examples. *International Journal of Production Economics,* vol. 59, pp. 519-528.