Study and design of a new policy for the storage and distribution of Nestlé Portugal's Point-of-Sales materials

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Abstract

Logistics is a key activity for an organization that aims to reduce costs, increase the service quality and reduce time, which requires a continuous improvement of processes and operations. This paper arises in this context and presents a case study developed at Nestlé Portugal, related to the storage and distribution operation of Point-of-Sales (POS) materials, which are used to promote Nestlé's brand at the point of sale.

The above referred operation suffered from inefficiencies associated with the lack of control and information on the eight warehouses used at that time. Therefore, Nestlé Portugal decided to change the management process of these materials and to centralize their storage in a single warehouse at national level.

The main objective of this research was to develop a model to evaluate and compare the previous and the current situation of the operation, previously described, together with other intermediate solutions considering different degrees of centralization. In the first step, it was developed a causal map that provided an inclusive understanding of the relevant aspects of the problem. In the second step, it was constructed a multi-criteria evaluation model using the MACBETH approach, which allowed to evaluate the four alternatives using as criteria the fundamental points of view identified during the first step. Finally, possible improvements for the two best ranked alternatives were discussed.

Key words: inventory centralization, causal mapping, multi-criteria analysis, MACBETH.

1. Introduction

Point-of-Sales (POS) materials are a useful marketing tools and aim to attract customers' attention and promote the brand at the point of sale. In April 2015, the Nestlé's Marketing and Sales department was responsible for the storage and distribution operation of POS materials. The different types of products, divided into eight business categories, have different marketing groups, and each of them managed their POS materials. Each marketing group decided on which logistics operator to work with and the number of warehouses, and this operation's management was not integrated.

There was no control over inventory and costs. It was not known which materials were in stock, nor their quantities and conditions. Records were not kept, and it was impossible to trace the product. Consequently, the materials were sometimes shipped in the wrong quantities or in poor conditions, and obsolete products were stored, causing unnecessary storage costs. There was also no standardization, neither defined norms and existed several storage and distribution tariffs.

This led to the detection, by the heads of the Nestlé Portugal Physical Logistics department, the need to change this situation. To this end, it was decided to centralize all the storage of POS materials in a single warehouse and change this material's management and control process.

The objective of Nestlé was that the POS materials' management operation was transversal to all the marketing groups. They considered necessary to define a logistic model that would allow the increase of the control and traceability of the materials and to reduce costs. It was necessary to define a responsible for the storage and distribution of the POS material, to define tools of management and to make available the appropriate information on the inventory. Nestlé also considered important to work with only one logistics operator to simplify the management of the operation.

This paper aims to evaluate the current and the previous situation and two intermediate alternatives considering different degrees of centralization.

The remainder of this paper is organized as follows: section 2 reviews the methods and approaches to address Nestlé's problem; section 3 describes the methods selected; section 4 describes the application of the methods to Nestlé's problem, and section 5 concludes this paper with some final remarks and a proposal of future work.

2. Literature Review

2.1. Centralization *versus* decentralization

It is important to define two distinct types of inventory system: decentralized and centralized. The decentralized system is a system in which a separate inventory is kept to satisfy the demand at each source of demand. The centralized system is a system in which all demands are satisfied from one central warehouse (Chen & Lin, 1989). Figure 1 represents, in a simplified way, these two types of systems, being A_n warehouses, and C_n search sources (e.g. clients or markets).

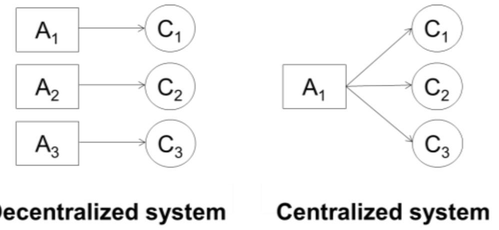

Figure 1. Schematization of a decentralized system and a centralized system

Several studies were carried out on the effects of centralization (see Maister, 1976; Das & Tyagi, 1997; Simchi-Levi et al., 2003; Goh & Lim, 2014). It is important to redrawn from this studies that in a centralized system the storage costs tend to be lower, since safety stock decreases; the distribution costs and the delivery time tend to be higher, since all sources of demand are met from a central warehouse. However, the determination of the appropriate degree of centralization should be based on demand and industry data for each situation.

2.2. Problem structuring

In recent years, users of multi-criteria evaluation methodologies have emphasized the importance of problem structuring in the process of building an evaluation model (Montibeller et al., 2008). There are some structuring techniques that can be useful, especially when dealing with complex situations involving multiple decision-makers and with many issues to be addressed simultaneously. Post-its sessions (Belton, 1999) and cognitive maps (Eden, 2004) are examples of such techniques, which can facilitate group work and help structure points of view.

The post-its session is an approach that consists in first capturing the individual perspectives of each actor, asking the decision-makers to write their ideas in post-its and then share them in a group, placing the post-its on a wall.

Cognitive maps, or causal maps, are one of the most commonly used techniques for problem structuring (Belton et al., 1997; Bana e Costa et al., 1999). Usually these maps are obtained through interviews and their purpose is to represent the problem/subject as a decision-maker perceives it, in the form of a means-ends network structure (Belton & Stewart, 2002). This structure is composed of nodes, representing concepts, and arrows, which represent connections between these concepts and whose direction implies causality (Eden, 2004).

In some cases, especially when dealing with a group of decision-makers, the two techniques described can be used together (Bana e Costa et al., 2014). The post-its session allows, at an initial phase, to identify and clarify the points of view and, later, the organization of these concepts on a causal map allows them to be grouped and to understand the cause-effect relationships or means-ends between them (Bana e Costa & Beinat, 2005).

2.3. Multi-Criteria Decision Analysis

Multi-criteria decision analysis is described as the collection of formal approaches that seek to consider several criteria to help individuals or groups (decision-makers) explore decisions that matter (Belton & Stewart, 2002).

In this chapter, some multi-criteria analysis methods will be described, such as methods based on the value theory (MAVT), outranking methods and AHP.

2.3.1. Multi-attribute Value Theory

Multi-attribute value theory (MAVT) is one of the most widely applied multi-criteria methods. Several approaches are based on this theory, for example, SMART (Edwards & Barron, 1994) and MACBETH (Bana e Costa & Vansnick, 1994).

The aim of this approach is to develop a way to associate a real number to each alternative, with the purpose of creating an order of preference between them, consistent with the decision-maker's value judgments.

The overall score of each alternative is obtained by aggregating the value of their performances in each evaluation criteria, using the additive model, as shown in equation 1.

$$V(A) = \sum_{i=1}^{n} w_i \, v_i(A_i) \qquad (1)$$

$$with \sum_{i=1}^{n} w_i = 1 \, , w_i > 0 \; and$$

$$\begin{cases} v_i(good) = 100 \\ v_i(neutral) = 0 \end{cases}, j = 1, \dots, n$$

Being:

$V(A)$ − overall value of alternative A

w_i − weight of criterion *i*

$v(A_i)$ − partial value of alternative A on criterion *i*

$v_i(good)$ and $v_i(neutral)$ − assigned values to "good" and "neutral" performance levels, for each criterion (defined as 100 and 0, respectively)

MACBETH

MACBETH (Measuring Attractiveness by a Category-Based Evaluation Technique), developed by Bana e Costa & Vansnick (1994) is an interactive multi-criteria decision analysis approach based on the MAVT. This approach is used to build a quantitative (numerical) value model based on qualitative (nonnumerical) pairwise comparison judgments.

SMART

The Simple Multi-Attribute Rating Technique (SMART), was developed by Edwards (1977) is also based on the MAVT. Using this methodology, the performance of the alternatives in each evaluation criterion is evaluated through the direct assignment of scores and the criteria weights are obtained through quantitative judgments of the decision-maker.

2.3.2. AHP

The Analytic Hierarchy Process (AHP), developed by Saaty (1980), is a theory of measurement through pairwise comparisons and relies on the judgements to derive priority scales. Like MAVT, it is based on an additive model, however the two methodologies differ mainly in terms of the underlying assumptions about preference measurement, the methods used to elicit preference judgements from decision-makers, and the means of converting these into quantitative scores (Belton & Stewart, 2002).

Despite its extensive use, this methodology has been the subject of several criticisms about its validity (see Belton & Stewart, 2002; Smith & von Winterfeldt, 2004; Bana e Costa & Vansnick, 2008).

2.3.3. Outranking methods

The outranking approaches differ from the MAVT approaches in that there is no underlying aggregative value function. The output of an analysis is not a value for each alternative, but an outranking relation on the set of alternatives. An alternative A outranks another alternative B if, given all the available information regarding the problem and the decision-maker's preferences, there are enough arguments to conclude that A is at least as good as B and no strong argument to the contrary (Belton & Stewart, 2002).

The two most prominent outranking methods are the ELECTRE family of methods, developed by Roy (1968) and PROMETHEE developed by Brans & Vincke (1985).

2.3.4. Choice of methods to be applied in the case study

To structure the problem will be developed a causal map, with the support of the Decision Explorer software (Banxia Software Limited, 2002). This is one of the most used techniques for structuring problems and allows to deal with their complexity. Since the group of decision-makers is composed of only two people, was not detected the need to use the post-its technique to simplify the process of gathering and sharing ideas.

For the development of the evaluation model it was decided to use, among the methods described above, the MACBETH approach. This approach was integrated in the M-MACBETH software (Bana e Costa et al., 2005) which allows not only to create an additive value model and analyse the sensitivity and robustness of the model's results, but also to detect inconsistencies in the decision-maker's judgments.

The main difference of this method, when compared, for example with SMART, is that it only requires qualitative judgments from a decision-maker to assess value scales and to weigh the criteria, whereas SMART requires quantitative judgments. Thus MACBETH can be a better choice when dealing with decision-makers with greater fluency and lower numerical aptitude (Fasolo & Bana e Costa, 2014).

Although AHP is a method used in several cases and well referenced in the literature, it was decided not to use it since its application has serious limitations (see section 2.3.2).

Outranking methods have also been excluded since it is intended to use a method for obtaining a quantitative measure, which provides not only an overall ranking of alternatives but also indicates the value difference between them.

3. Methodology

3.1. Causal maps

A causal map is a network of concepts, represented by nodes, which are connected by arrows that indicate the type of connection: causality, influence or implication (Axelrod, 1976). The links are arrows with a positive or negative sign, that represent a positive or negative influence respectively.

In a causal map is intended to identify each node as having two contrasting poles, separated by "…", that should be read as "rather than" (Eden, 2004).

Causal maps, when used for supporting decision making, usually assume a means-ends structure, which positions decision-makers' ends/goals at the top (nodes with only in-arrows) and decision options/means at the bottom (nodes with only out-arrows).

3.2. MACBETH

MACBETH is an interactive multi-criteria decision analysis approach used to build a quantitative value model based on qualitative value judgments. The purpose of this technique is to measure the attractiveness of the alternatives through a non-numerical pairwise comparison questioning mode that asks the decision-maker about the difference in attractiveness between two options (or two performance levels). This difference is assessed using a semantic scale composed by seven categories: indifferent, very weak, weak, moderate, strong, very strong or extreme (Bana e Costa et al., 2012)

According to Bana e Costa et al. (2008) the MACBETH approach for developing the multi-criteria model consists of three phases: structuring, evaluation and testing.

Structuring

This phase includes the criteria definition. A criterion is a tool used to evaluate alternatives in terms of a certain point of view considered fundamental by the decision-maker. Each evaluation criterion should be an independent axis of comparative evaluation (Bana e Costa et al., 2002).

The structuring phase also includes the association of a descriptor of performance to each criterion. A descriptor is an ordered set of plausible impact levels and is intended to serve as a basis for describing the performance of the alternatives regarding to each criterion.

Evaluation

The evaluation phase includes the value function construction and the criteria weighting.

Using the MACBETH approach value functions are constructed through qualitative judgments about between different levels of the descriptor of performance. The value function obtained for each criterion allows quantifying the partial attractiveness of the respective levels of performance.

The weighting coefficients allow the aggregation of the partial values obtained by the alternatives in each criterion, required to calculate the overall value of each alternative. These coefficients can also be obtained through qualitative judgments from decision-makers about differences in attractiveness.

Testing

In the last phase, sensibility and robustness analysis of the results are performed to allow an appropriate drafting of recommendations.

The sensitivity analysis consists of studying the changes that may occur in the global ordering of the alternatives when the relative weight of a given criterion is modified, keeping the proportion among other weights.

The robustness analysis can be done to explore whether relations of dominance and global preference hold between options under varying amounts of information and differing degrees of imprecision or uncertainty.

There are three types of information: ordinal, MACBETH and cardinal. Ordinal information refers only to ranking, thereby excluding any information relating to differences of attractiveness. MACBETH information includes the semantic judgements entered into the model; however, it does not distinguish between any of the possible numerical scales compatible with those judgements. Cardinal information denotes the specific numerical scale validated by the decision-maker.

In this analysis, two types of dominance can be observed:

- Alternative A dominates alternative B if A is not less preferred than B in all the criteria and A is preferred to B in at least one criterion. This type of dominance is represented in M-MACBETH by a red triangle.
- Alternative A additively dominates alternative B if for a set of given assumptions related with the parameters of the additive model option A is always better valued than option B. This type of dominance is represented in M-MACBETH by a green plus sign.

Lack of dominance is represented by a question mark.

4. Case Study

4.1. Structuring the problem – causal map

To understand what influenced the heads of the Physical Logistics department of Nestlé Portugal to detect the need to change the logistic model for the storage and distribution of the POS materials, interviews were carried out with members involved in the process. First, individual interviews were held with two members of the Physical Logistics department. Subsequently the map was developed and improved through joint interviews to obtain more detailed information about the problem.

To gather qualitative information on the subject, an iterative method was used, asking the decision-makers: "why the need to change the logistic model?", followed by "why?" for each answer obtained to this question and so on. It was also questioned “how” a certain objective (final or intermediate) could be achieved. This method was also used to understand the reasons for not changing the current situation, until the process was finished and the final and intermediate objectives defined.

Finally, the causal map was analysed and validated by the decision-makers, and is shown in Figure 2.

From the analysis of the map it is possible to identify the concepts that appear as final objectives, those that are at the top of the map, namely:

- Increased control over POS materials (inventory, quality, traceability) and costs;
- Simplification and organization of the operation;
- Reduced storage costs;
- Reduced transportation costs (outbound);
- Greater accessibility for the client;
- Reduced delivery time.

Although the concepts "delivering the right product in the right amount (flexibility)", "increased system reliability" and "increased agility, leanness and responsiveness" appear even higher in the map structure, these are considered strategic objectives of the company, i.e. those who are influenced by all decisions made over time by the decision-maker.

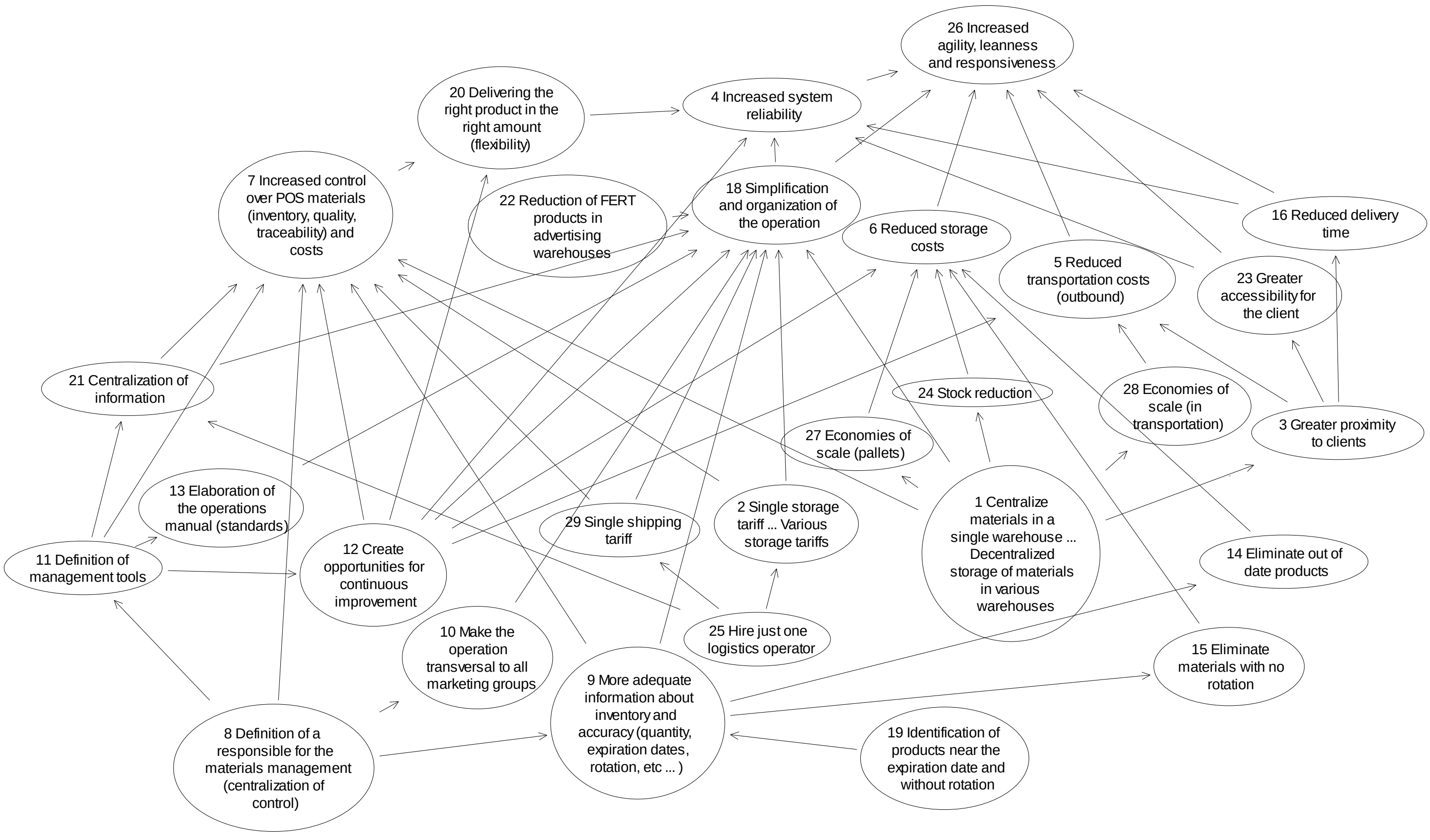

Figure 2. Causal map

4.2. Building the multi-criteria evaluation model

4.2.1. Structuring

4.2.1.1. Definition of evaluation and acceptance criteria

For an alternative to be considered in an evaluation model, it has sometimes to meet some minimum admissibility thresholds that are defined in the acceptance criteria, otherwise it will be rejected. In this case study, acceptance criteria were not defined since it is intended to compare the current situation with the previous situation.

Considering the analysis performed on the causal map, the evaluation criteria of the model were defined and are structured in the value tree shown in Figure 3.

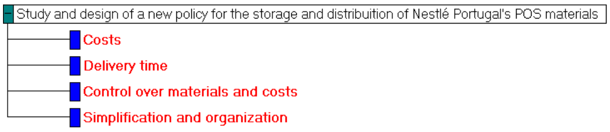

Figure 3. Value tree

Costs - The extent to which transportation and storage costs affect Nestlé.

Delivery time - The extent to which the time elapsing between the placement of an order and its receipt by the customer affects Nestlé.

Control over materials and costs - The extent to which each alternative allows Nestlé to have control over materials and costs, knowing exactly what materials are stored, their quantities and conditions, and to know the total costs in detail.

Simplification and organization - The extent to which each alternative simplifies the operation for customers (internal and external), allowing them to access information and order materials easily and rapidly.

Although appearing on the map as one of the final objectives, the concept of "accessibility" would not be an evaluation criterion because it is redundant.

4.2.1.2. Definition of the descriptors of performance

After defining the evaluation criteria, it was assigned to each of them a descriptor of performance. The descriptors are composed of different levels of performance sorted by descending order of attractiveness.

The descriptors were directly assigned to the criteria "costs" and "delivery time", however to the criteria "control over materials and costs" and "organization and simplification", the descriptors were constructed, since they intend to evaluate several characteristics of the alternatives. For the construction of these descriptors the causal map was accurately analysed to clarify which concepts could affect the control over materials and costs and which ones could affect the simplification and organization of the operation.

The reference levels of the descriptors of performance for the criteria “costs” and “delivery time” (shown in Table 1 and 2, respectively) were obtained by questioning the decision-makers about what value would correspond to a "Neutral" level, a level that is neither attractive nor repulsive, and which would correspond to a "Good" level, which corresponds to an unquestionably attractive level.

Table 1. Reference levels ("Good" and "Neutral") of the criterion "costs"

	Performance levels
Good	€ 9000
Neutral	€ 12000

Table 2. Reference levels ("Good" and "Neutral") of the criterion "delivery time"

	Performance levels
Good	16 hours
Neutral	24 hours

As mentioned, several characteristics of the alternatives contribute to their performance in the criterion "control over materials and costs". Consequently, it was decided to fix at this stage only the reference levels "Good" and "Neutral", shown in Table 3. The performances of the alternatives in this criterion will be judged later by comparing the alternatives profiles with the two reference levels.

Table 3. Reference levels ("Good" and "Neutral") of the criterion "control over materials and costs"

	Performance levels
Good	The inventory is centralized in a single location. Only one logistic operator is hired. The information about the materials is adequate, management tools are defined and the operation is transversal to all marketing groups.
Neutral	The inventory is not centralized in a single location, being distributed by three warehouses. Two different logistics operators are hired. Information about the materials is adequate, management tools are defined and the operation is transversal to all marketing groups.

The levels of the descriptors of performance for the criterion “simplification and organization” are described and ordered by preference in Table 4. It should be noted that these levels are the ones considered plausible by the decision-maker and are not considered levels with more than two access platforms.

Table 4. Reference levels ("Good" and "Neutral") of the criterion "simplification and organization "

	Performance levels
N1 = Good	An operations manual is defined. There is only one access platform with centralized material information.
N2 = Neutral	An operations manual is defined. There are two access platforms, so the material information is not centralized.
N3	An operations manual is not defined. There is only one access platform with centralized material information.
N4	An operations manual is not defined. There are two access platforms, so the material information is not centralized
N5	An operations manual is defined. There is no access platform.
N6	An operation manual is not defined. There is no access platform.

4.2.1.3 Definition of the alternatives

The objective of this paper was to evaluate different alternatives, namely the previous situation, the current situation and two fictitious situations considering different degrees of centralization.

A1 – Current situation: 1 warehouse (in Lisbon); 1 logistic operator; 1 access platform; adequate information; operation transversal to all marketing groups; management tools defined; operations manual created.

A2 – Previous situation: 8 warehouses distributed across the country; 4 logistics operators; no access platform; inadequate information; operation was not transversal to all marketing groups; no management tools defined; no operational manual created.

A3 – Fictitious situation: 2 warehouses (1 in Lisbon and 1 in Porto); 1 logistic operator; 1 access platform; adequate information; operation transversal to all marketing groups; management tools defined; operations manual created.

A4 – Fictitious situation: 3 warehouses (1 in Lisbon,1 in Porto and 1 in Faro (during 4 months)). 2 logistic operators; 2 access platforms; adequate information; operation transversal to all marketing groups; management tools defined; operations manual created.

Table 5 shows the performance of the alternatives in the criteria "costs" and "delivery time"", which were later introduced in M-MACBETH. The costs and the delivery time were estimated considering the observed data and the theoretical concepts studied in section 2.1.

Table 5. Performance of the alternatives in the criteria "costs" and "delivery time"

	A1	A2	A3	A4
Delivery time (hours)	30	16	23	22
Costs (€)	11100	23500	11700	12800

4.2.2. Evaluation

4.2.2.1 Construction of value functions

With the purpose of associating a value to the performance of the alternatives in each criterion, considering the partial attractiveness in this criterion, value functions were built, using the MACBETH approach.

Decision-makers were asked to provide qualitative judgments about the difference in attractiveness between each two ordered levels of performance for each criterion, using the MACBETH semantic scale. This scale consists of seven categories: indifferent, very weak, weak, moderate, strong, very strong or extreme.

For example, decision-makers were questioned about the difference in attractiveness between the performance levels “7500" and “9000" of the criterion “costs”, which they considered "moderate". These questions were repeated between each two consecutive performance levels and the qualitative judgments were introduced into the M-MACBETH matrix, shown in Figure 4.

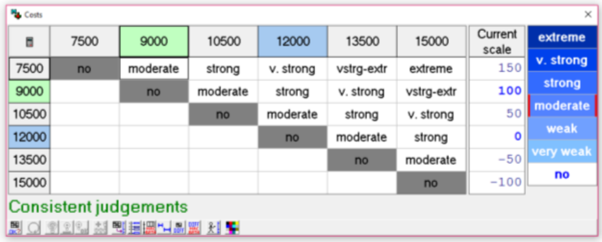

Figure 4. Judgments matrix for criterion “costs”

After verifying that the matrix had no inconsistencies, the software proposed a numerical scale that assigned scores to the different performance levels of the descriptor in relation to the reference levels "Good" and "Neutral", whose scores were set at 100 and 0 respectively. In Figure 5 is shown the proposed scale for the criterion “costs”, which was shown to decision-makers for validation and adjustment, if needed.

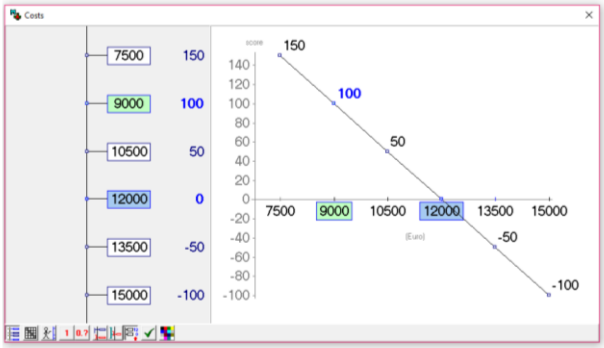

Figure 5. Value scale for criterion “costs”

This process was repeated for all the evaluation criteria.

4.2.2.2 Criteria weighting

With the aim of weighting the evaluation criteria, the decision-makers were asked to consider a fictitious alternative for each criterion with a performance corresponding to the "Good" reference level in that criterion and a "Neutral" performance in the other criteria. In addition, they were asked to consider a fictitious alternative ("Neutral all over") with "Neutral" performances in all the criteria.

Subsequently the decision-makers were asked to order the fictitious alternatives by descending preference and to pairwise compare each two of them using the MACBETH qualitative categories of difference in attractiveness. These judgments were introduced in the matrix shown in Figure 6.

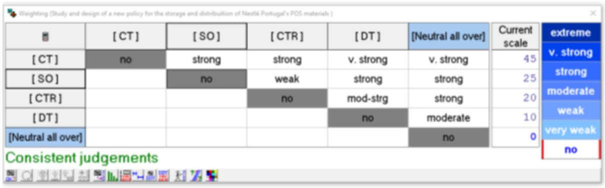

Figure 6. Weighting judgments matrix

After verifying the consistency of the judgments, the software calculated the criteria weighting coefficients and presented them in a histogram, as shown in Figure 7. The decision-makers made some necessary adjustments so that the coefficients adequately represented the relative importance of the neutral-good swing defined in each criterion and validated these results.

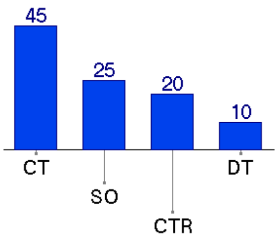

Figure 7. Weights histogram

4.2.3. Analysis of results

After constructing the value functions for each of the evaluation criteria and weighting them, M-MACBETH calculated the overall scores of the alternatives A1, A2, A3 and A4, shown in Figure 8 (see "Overall" column), using the additive model as described in section 2.3.1.

Options	Overall	CT	DT	CTR	SO
[Good all over]	100.00	100.00	100.00	100.00	100.00
A1	51.00	30.00	-75.00	100.00	100.00
A3	44.75	10.00	12.50	70.00	100.00
[Neutral all over]	0.00	0.00	0.00	0.00	0.00
A4	-9.50	-26.67	25.00	0.00	0.00
A2	-292.50	-383.33	100.00	-150.00	-400.00
Weights :		0.4500	0.1000	0.2000	0.2500

Figure 8. Overall scores of A1, A2, A3 and A4

M-MACBETH allows to analyze the difference profiles of the alternatives. In Figure 9 is shown the weighted differences profile of alternatives A1 and A2, the current and the previous situation, respectively. Since it is a significant difference of scores, that corresponds to more than three times the difference between an alternative that had a "Good" performance in all the criteria and another one that had a "Neutral" performance in all the criteria, it is possible to observe that changing the storage and distribution operation of POS materials proved to be very advantageous for Nestlé. Apart from the criterion "delivery time", whose average value increased with the centralization of inventory, in all other criteria the value of A1 proves to be much higher than the value of A2.

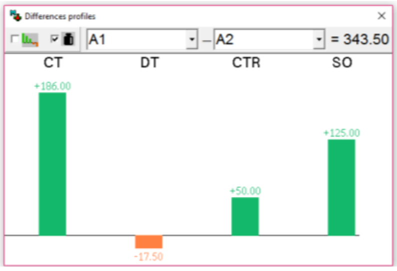

Figure 9. Weighted differences profile of A1 and A2

It is also verified that the overall scores of the alternatives A1, the current, and A3 are quite close, as can be seen in the weighted differences profile of Figure 10. Therefore, the analysis of the results and the test phase mainly focus on these two alternatives.

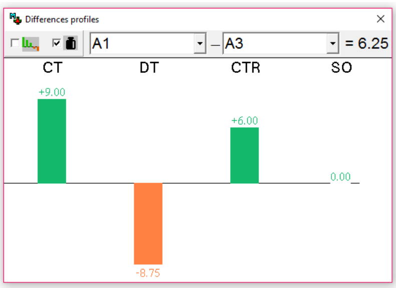

Figure 10. Weighted differences profile of A1 and A3

It was then intended to analyze how the alternative A3 could become at least as attractive as the A1 alternative. A3 overall score would have to increase by 6.25 units.

The difference in control between the alternatives is inherent in the degree of centralization, so it would be difficult to change it. For these reasons the improvement of alternative A3 would have in terms of costs of the operation. It was then necessary to calculate the value of 6.25 units in euros, considering that the difference between the level "Good" (100 points) and the level "Neutral" (0 points) corresponds to 3000 €/month and the weight of the criterion "costs" is 45%. This value (x) was calculated through equation 2.

$$x = \frac{\frac{(12000 - 9000)\times 6.25}{100 - 0}}{0.45} = 416.7\ €/month \qquad (2)$$

If the costs of A3 were on average 11283.3 €/month, it would be as attractive as A1. This cost reduction is not very significant and could be easily achieved with some improvements. For example, materials with less rotation could be identified to be stored only in the warehouse in Lisbon. This would reduce storage costs and the transportation costs would not be significantly increased, since the materials would be distributed infrequently.

In addition, a more accurate demand forecast could lead to a decrease in the safety stock required to meet the demand, reducing the storage costs. This storage costs reduction may be more significant in alternative A3 because it includes the cost of safety stock in 2 warehouses and, as explained in section 2.1, the higher the degree of centralization, the lower the safety stock required. With the new material management policy the demand forecast accuracy will tend to increase over time, as it is still in the implementation phase, however, this can be further improved by more frequent studies and analyses, that can be done together with the heads of marketing groups of each business category, to know what they will need, when and where.

The reduction in storage costs can also be achieved by eliminating articles in storage. For example, if a given type of advertising material (a promotional stand or shelves) is stored for each of the existing business categories, it may be studied whether it is necessary to store that amount or whether the material can be shared and thus reduce the quantity in the warehouse.

In alternative A3, although the value in the "delivery time (TE)" criterion is higher than the "Neutral" level, if the delivery time was even lower, it could obtain a higher score. It was calculated through equation 3 how many hours (y) of average delivery time should be reduced so that A3 would get the same score as A1. This would happen if the average delivery time decreased by 5 hours, that is, if it was 18 hours. For any delivery time less than 18 hours A3 would be preferred.

$$y = \frac{\frac{(24 - 16)\times 6.25}{100 - 0}}{0.10} = 5\ hours \qquad (3)$$

For this case study, the delivery time would be difficult to reduce, and negotiations with logistical operators would be needed. The delivery time could be reduced, for example, by changing the picking strategy to a faster one, by streamlining the document management or other actions that could shorten order preparation time. Increasing the freight frequency could also decrease the average delivery time.

On the other hand, improvements could also be applied to the current alternative (A1), so it would become even more attractive. The average delivery time could be reduced through the actions mentioned above. The delivery time of A1 is 30 hours, however if it corresponded at least to a "Neutral" level (24 hours) A1's overall score would increase by 7.5 units.

Reducing costs could also increase the attractiveness of A1. Storage costs could be reduced through the same actions suggested for alternative A3, however, as mentioned, with less impact. Though, transportation costs can also be reduced, and with a greater impact on alternative A1. This reduction can occur if the orders that are delivered in the same area are aggregated, thus obtaining economies of scale and reducing the cost per kilogram. On the other hand, the implementation of this policy could mean an increase in the average delivery time, associated with the need to aggregate orders, and this should be studied in detail.

Finally, the alternative A4, which considers the existence of a warehouse in Lisbon, one in Porto and one in Faro (during 4 months), and in which two logistic operators are hired, is not attractive, and obtained a negative score.

XY map

It is possible to analyze, using M-MACBETH, the multi-criteria value obtained by each alternative versus the cost of this alternative, through an XY map, as in Figure 11. In this map the cost of each alternative goes on the x-axis and the score obtained by the alternatives in the criteria "delivery time", "control over materials and costs" and "simplification and organization" goes on the y-axis. The weight of the criterion "costs" (45%) was proportionally redistributed by the other criteria.

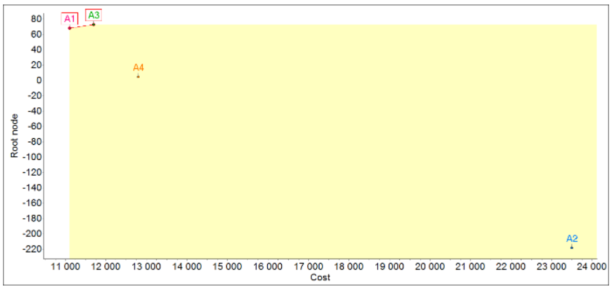

Figure 11. XY map

In the map, the efficient boundary, which includes the efficient alternatives A1 and A3, was drawn. The other alternatives (A2 and A4) are dominated and therefore should not be selected.

A1 obtained an overall score equal to 68.19 and has a cost € of 11100, while A3 obtained a score equal to 73.18 and has a cost of € 11700. Thus, an increase of 4.99 points in the benefit is associated with an increase of € 600 in cost and improving a unit of value in performance between A1 and A3 corresponds to a cost of € 120.2 (a), calculated by equation 4.

$$a = \frac{11700 - 11100}{73.18 - 68.19} = 120.2\ €/unit \qquad (4)$$

It was then necessary to understand if the decision-makers would be willing to pay this amount for each unit of value. They were asked how much they would be willing to pay to swing from "Neutral" (24 h) to "Good" level (16 h) in the criterion "delivery time". They assumed that they would be willing to pay approximately € 1000. Once the criterion "delivery time" has a weight of 18.18%, swinging from "Neutral" level (0 points) to "Good" (100 points) in this criterion would mean an increase in the overall score of 18.18 points. It was calculated, through equation 5, how much would the decision makers be willing to pay for the improvement of one unit in the overall score (b).

$$b = \frac{1000}{(100 - 0) \times 0.1818} = 55.0\ €/unit \qquad (5)$$

Thus, the decision makers would not be willing to pay the required € 120.2 per unit of the overall score, which reinforces the preference of alternative A1, the efficient alternative with the lower cost.

4.2.4. Test

After obtaining the results, sensitivity and robustness analysis were performed.

Sensitivity analysis

In a sensitivity analysis, the weight of the criterion being analysed goes on the x-axis. In the y-axis goes the overall score of each alternative, which changes when the weight of the criterion varies from 0% to 100%. The white area bounded by dashed green lines represents the range within which the weight of the criterion can be modified, keeping the proportion among other weights, so that order relations between judgments are not disrespected.

Figure 12 shows a sensitivity analysis graph for the weight of the criterion “delivery time”, the one that has the lowest weight (10%).

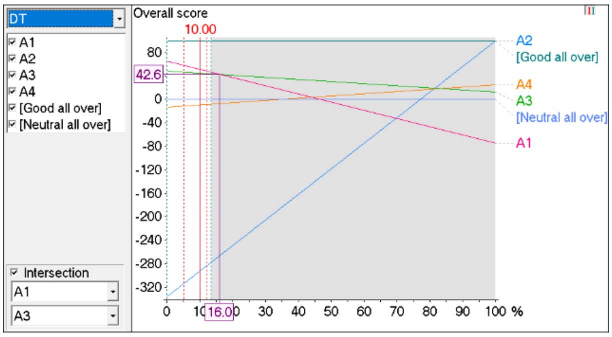

Figure 12. Sensitivity analysis graph for the weight of the criterion “delivery time”

If the weight of this criterion was 16%, A1 and A3 would have the same overall score and if it was greater than 16% the preferred alternative would become A3 instead of A1. This weight variation is not included in the range within which the weight of the criterion can be modified.

During this sensitivity analysis, decision-makers reinforced the idea that moving the performance of the alternatives from "Neutral" to Good" in criterion "delivery time" is in fact less relevant than in the other criteria. Therefore, they considered that the results correctly reflected their preferences.

Robustness analysis

Figure 13 shows the robustness analysis performed on the model, taking into account all types of information and a variation of ±5% in the cardinal information. It is possible to verify that there is no dominance between the alternatives A1 and A3.

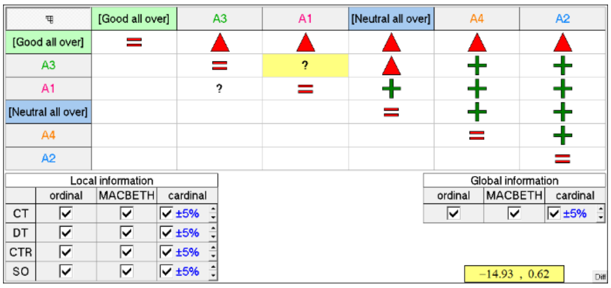

Figure 13. Robustness analysis

In the bottom right corner of Figure 13 is represented the range of variation between A1 and A3 in this robustness analysis. The minimum overall value difference of the alternatives is 0.62 and the maximum overall value difference is -14.93. Since one value is positive and the other is negative there is no dominance between the alternatives. Up to a variation of ±4% in this information it is robust to say that A1 additionally dominates A3.

Figure 13 also shows that A3 dominates the "Neutral all over" alternative (in the classical sense of dominance). This happens because the performance of alternative A3 is positive in all criteria, that is, it is always superior to the performance of the alternative "Neutral all over". It is also possible to verify that the alternative "Good all over" dominates the other alternatives, which means that there is no alternative that has, in any criterion, a performance with a score superior to 100.

Scenario analysis

The decision-makers considered that the estimated costs and delivery time for the alternatives may vary within a given range.

They consider that, in the worst-case scenario for A1, the cost of this alternative may be € 11400 (per month). In this scenario, the difference between the overall value of A1 and A3 would be only 1.75 and not 6.25 as noted previously in Figure 10, which would make it more difficult to identify the preferred alternative.

On the other hand, in the best-case scenario for A1, the cost of this alternative may be € 10800 (per month), and the difference between the scores of the alternatives would be 10.75. In this case, it would be more robust to say that A1 is better than A3.

Decision-makers also consider that, in the best-case scenario for A1, the delivery time for this alternative is 28.5 hours. In this case, the difference between the scores of A1 and A3 would be 8.13 points. However, as stated in section 4.2.3, it is difficult to reduce the average delivery time of the alternatives in this case study.

The study of these scenarios once again verifies that alternatives A1, which is currently effective, and the fictitious alternative A3 have similar performances and that a variation in costs or delivery time could mean a change in the rank of these alternatives. This analysis also reveals the importance of making estimates as accurate as possible so that a better choice can be reached.

5. Conclusions and future work

The present work is within the scope of the improvement of logistics operations, focusing on the centralization versus decentralization of Nestlé Portugal POS materials' inventory.

The development of a causal map helped to structure the problem, allowed to organize the ideas and gave rise to new concepts, about which there had not yet been reflection. This was a very laborious process, since it is necessary an initial setting of the decision-makers to the method. However, it proved to be extremely advantageous for both parties as it provided a better understanding of the problem. An in-depth analysis of the causal map was carried out to identify the fundamental points of view regarding the case study.

Afterwards, the development of the multi-criteria evaluation model alongside with de decision-makers, using the MACBETH approach, served to evaluate the attractiveness of the four alternatives.

Subsequently, after applying the additive model, it was verified that the change from the previous situation to the current situation was very advantageous for Nestlé, due to the significant difference in the scores obtained by the alternatives that correspond to these situations. It was also verified that only two alternatives obtained positive scores, A1 (the present situation), with 51 global points, and A3 (a fictitious situation), with 44.75 global points, which are the alternatives that have a greater inventory centralization, using one and two warehouses respectively. The testing phase focused on these alternatives and allowed to study the model's behaviour when there's a change on the criteria's weights, on the scores of the alternatives in each one of the evaluation criteria or on the performance of the alternatives in some of these criteria, which led to the study of possible improvements.

With the completion of this phase the proposed objective was fulfilled: was developed and tested a model that allowed to study different alternatives to a real problem of Nestlé. As far as it was possible to verify, in the literature there were no applications of multi-criteria evaluation methodologies to decisions about inventory centralization and, thus this work could serve as a basis for the study of similar problems.

The work developed was validated by Nestlé managers and they considered it useful for a better understanding of the evaluated alternatives, since it allowed to quantify the differences of attractiveness between them and to explore possible improvements. They also considered that the MACBETH approach enabled them to easily express their preferences and provided a detailed understanding of the dimensions of the case study.

The model can also be used to study future improvements in any of the evaluation criteria, although it presents some limitations concerning some criteria's descriptors of performance. The performance levels' scores of the criteria "control over materials and costs" were obtained through a direct comparison of the alternatives and the scores of the criteria "simplification and organization" were obtained only for the currently plausible levels. For this reason, it might be necessary to construct new value scales for these criteria.

For future work, it would be interesting to evaluate another alternative, similar to A3, but considering to store in Porto only the materials with high turnover rate. The advantages of centralization, specifically the reduction of storage costs, are greater for Slow Moving Items (SMI), items with low turnover rate (Goh & Lim, 2014). In this alternative, these materials would only be stored in Lisbon, which would allow a reduction in storage, but the items with the highest turnover would also be stored in Porto, causing the reduction of transportation costs, that occurs with decentralization. This alternative could represent an intermediate situation between alternatives A1 and A3, with the advantage of reducing storage costs as in A1 and the advantages of reducing transportation costs and the average delivery time as in A3.

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