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# THE APPLICATION OF MULTICRITERIA DECISION ANALYSIS IN AN ISO 9001 IMPLEMENTATION PROBLEM

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**KEYWORDS**
Decision making, Multi-criteria decision

**ABSTRACT**

Nowadays, organizations are challenged with several problems which envolve financial and non-financial impacts. Several tools and methodologies had been created to help them in the process of decision making. These methodologies have in consideration the important aspects for the companies and the possible results obtained for each criteria under analysis.
In the presented study, we used a decision making methodology based on value functions, to help make decisions in a context of an hyphotetical problem related with the impacts of the ISO 9001 implementation. This is one of the most used methods for multi-criteria decision analysis. This study shows the utility of this method to solve problems with both types of criteria, financial and non-financial. Besides, it allowed to identify limitations of the application of this kind of methods such as the dependency of the opinion of the decision maker, that could result in different outcomes, according to his preferences. To mitigate this problem, a combination of decision making methodologies could help to achieve better results.

## INTRODUCTION

Presently, people and organizations are envolved in a complex environment which led to the necessity of making decisions. The need of making a decision, generally is associated with a problem. When this problem requires the consideration of only one variable/criteria, this problem is relatively easy to solve and it is possible to find an optimal solution (Løken, 2007). However, in a modern society, the multi-criteria decision analysis is necessary, because the problems handled involve several relevant variables with different objectives. Since in these cases is not possible to achieve an optimal solution, the multi-criteria decision analysis could aid the decision maker to choose the more convenient alternative for him, based on his preferences (Løken, 2007).

In this study, the problem on hand concerns the implementation of the ISO 9001, which can benefit with the application of a multi-criteria decision analysis. There is extensive literature about the implementation of ISO 9001, however the results concerning the impacts of this standard are not consensual and due to the lack of resources and time it was not possible to analyse this problem in a real context. However, the results of this study may be of interest, helping reflecting what may be relevant in the implementation of this standard. The method choosen was the weighted sum model (Triantaphyllou & Baig, 2005), because it was necessary to consider two criteria, a financial one (the cost) and a non financial one (the utility) for a total of eighty one alternatives, making it difficult the use other methods such as PROMETHEE and ELECTRE, since they are based in comparisons between alternatives (Dağdeviren, 2008; Løken, 2007). To complete the study, a sensitivity analysis to the variables which presented a possibility of variation was performed.
Thus, the paper is divided in 4 sections. The first section presents a summarized literature review of the topic under analysis. The next section named problem description presents the description of the problem studied. The following section presents the analysis and results of the study. Finnaly, the last section presents the main conclusions.

## LITERATURE REVIEW

The multi-criteria decision analysis (MCDA) is one of the most used techniques for decision problems resolution (Løken, 2007; Marttunen et al., 2017). It was already applied in areas such as energy, environmental sciences and financial decision (Bana E Costa et al., 2004; Butler et al., 1997; Kiker et al., 2005; Løken, 2007; Marttunen et al., 2017). These methods do not achieve the final result by themselfs, however they help the decision maker in the organization of the available information (Løken, 2007). In this type of problems, several decision alternatives are evaluated, each one caracterized by its specific attributes in each criterion (Løken, 2007; Triantaphyllou & Baig, 2005). Generally, the MCDA methods have one of the following objectives: to find the best solution, to group the alternatives in classes, to order the alternatives or present the overall performance of each alternative (Triantaphyllou & Baig, 2005). The objective is achieved through the consideration of all criteria choosen and the decision maker preferences (Kiker et al., 2005; Triantaphyllou & Baig, 2005). Recently, some researchers also considered the use of MCDA to other uses such as simplifying the communication, better exploration of the alternatives and expand learning (Marttunen et al., 2017).

The definition of the objectives in MCDA is one of the most important steps of any analysis to be made, since it will allow to define the best MDCA methodology to apply and it will shape the inputs needed to achieve a good solution for the problem (Weber et al., 1988).

To use these methodologies, relative or absolute information is necessary for all the criteria under analysis, for each alternative considered as a potential solution (Triantaphyllou & Baig, 2005). One of the main problems of MDCA is the quantification of all data which is presented in different scale units, even in problems that is possible to know the precise values for each criterion considered important to choose the best alternative. There are not a precise method to process data which is quantified in different forms (Triantaphyllou & Baig, 2005).

The decision making based on value functions is one of the possible methods used to compare different types of variables (Triantaphyllou & Baig, 2005). In this methodology, the diverse criteria is converted into a common adimensional scale, for example from 0 to 1, and aggregated with a weighting sum function (Kiker et al., 2005; Triantaphyllou & Baig, 2005). This way is achieved a overall result for each alternative and the main objective of the decision maker is to maximaze the final value or overall score (Kiker et al., 2005; Triantaphyllou & Baig, 2005). The prefereed alternative should satisfy equation 1 (Triantaphyllou & Baig, 2005) :

$$P_{WSM}^{*} = max_i \sum_{j=1}^{n} a_{ij} * w_j \qquad i = 1, 2, \ldots, m \qquad (1)$$

Where $w_j$ is the preference of the decision maker for the criterion j, and $a_{ij}$ is the adimensional value of the criteria j of the alternative i (Kiker et al., 2005; Triantaphyllou & Baig, 2005).

## PROBLEM DESCRIPTION

An organization intended to analyse the impacts of the ISO 9001 implementation, however they do not know which areas of the company should appear in the evaluation model neither which is the best option to do it. The initial idea was to maximize the utility of the study for the company and to minimize the costs. It is important to have in consideration that this is an hyphotetical problem, however the areas considered possible to be affected are based on the literature about impacts of ISO 9001 implementation (Aba et al., 2016; Heras-Saizarbitoria et al., 2011; Kafetzopoulos & Gotzamani, 2014; Kafetzopoulos et al., 2015; Marín & Ruiz-Olalla, 2011; E. Psomas & Kafetzopoulos, 2014; E. L. Psomas et al., 2013).

Based on the knowledge of the company relative to the ISO 9001, it is known that there are four areas which could suffer effects due to this standard implementation, namely: business performance, financial performance, operational performance, and quality performance.

It is also recognized that different motivations (internal or external) to implement the ISO 9001 will generate different results. When an organization refers its motivation is internal, it was considered there is a 60% probability of this being right and when it is refers that the motivation is external, it was considered there is a 80% probability of this being right.

Some other values were also defined for the exercise. If the real motivation to implement the ISO 9001 is internal, the probability of afecting de areas of the company are the following: Financial performance and Quality performance being afected simultanuosly is 50%, Quality performance is 20%, financial performance is 20% and Business performance is 10%.

When the real motivation is external, the influenced areas are the following: 30% financial performance, operational performance and quality performance being affected simultaneously, 25% operational performance and quality performance simultaneously and 10% for financial performance and operational performance simultaneously. There are also the possibility of affecting the areas of quality performance, operational performance and financial performance separatly, with probabilities of 10%, 10% e 5%, respectively.

To analyse “business performance”, the common duration is 3 months, but it could vary between 2 and 4 months. In the case of financial performance, the common duration is 1 month, and it could achieve 2 months. Relatively to the operational performance, the duration is 6 months. Finally, quality performance analysis need 2 months, and it can go until 3 months.

It is also necessary to pay attention that, when two or more areas are under study, they only can be analysed separately. The average cost for each month of study is 1000 euros, with a chance to variate between 800 and 1200 euros.

The attribution of the utility of each alternative is made based on the table 1. For example, if quality and operational areas are simultaneously used for the analysis, and only the quality suffers impact, the utility for the company of the study will be 2, because they expended money for the analysis of two areas and only one was correct. So, the best studies selected all the areas that suffer impact and none of them is consider a wrong area. So, utility 6 is the best result, corresponding to the alternative with 3 correct areas choosen for the study and none wrong, utility 5 is attributed to the cases were there are 2 correct areas and none wrong, utility 4 for 1 correct area and none wrong, utility 3 for 2 correct areas and one wrong, utility 2 for 1 correct area and one or two areas wrong, utility 1 when none of the areas choosen is affected.

Table 12: Utility values and respective description

| Utility | Description |
|---|---|
| **6** | all the 3 areas choosen suffer impact; |
| **5** | all the 2 areas choosen suffer impact; |
| **4** | The only area choosen suffer impact; |
| **3** | Two of all areas choosen suffer impact; |
| **2** | One of all areas choosen suffer impact; |
| **1** | None of the areas choosen suffer impact. |

The goal is to understand which is the best alternative for the company, considering the criteria under analysis, cost and utility. Figure 1 shows a representation of the problem in an influence diagram.

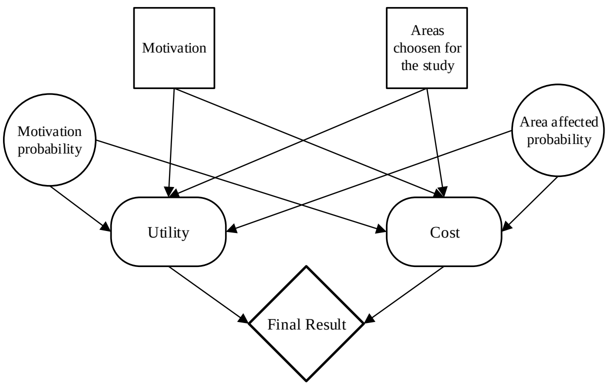


Figure 4: Influence Diagram of the problem under analisys

## ANALYSIS AND RESULTS

The comparation and aggregation of the different criteria is made through a weighted sum model (Triantaphyllou & Baig, 2005). This process requires to have a common scale, so the cost criteria was converted in an adimensional scale with maximum 1, correspondent to the maximum cost 1200 euros and minimum 0 correspondent to the minimum cost 800 euros and the utility criteria was also converted in an adimensional scale with maximum 1, correspondent to 6 and minimum 0 correspondent to 1.

Since this study considered criteria with different units, it is needed the opinion from the decision maker to convert the two different scales in a common one representing their value to the decision maker. After discussion, the conclusions are that the value function for the criteria utility follows an exponencial value function with a=2 presented in the equation 2 and the cost criteria follows a linear value function presented in the equation 3.

$$v_u = \frac{u-1}{6-1} \quad (2)$$

$$v_c = \frac{e^{2(\frac{13200-c}{13200-800})}-1}{e^2-1} \quad (3)$$

The decision maker also refered that the utility criteria is three times more important than the cost.

Using Microsoft Excel, it was possible to obtain the function values for each alternative through the equation 4 (these values are presented in annex and they were calculated based on the common values for each criterion of each alternative).

$$v(u,c) = k_u v_u + k_c v_c = 0{,}75 v_u + 0{,}25 v_c \quad (4)$$

Based on the results obtained, it is possible to conclude that the best alternative considers financial and quality areas and it should choose external motivation. These results could change based on the decision maker and also due to the variation of the values of each criteria.

A sensitivity analysis was made to understand the most critical variable that could have more impact on the final result. The variables presented in the problem that could change are related with the costs of the study, namely the time needed to evaluate the impacts of each area and the cost per month of the study. So, the variables considered to proceed with this analysis are the time study of the areas financial, quality and business and the monthly cost.

Figures 2, 3, 4 and 5 present the graphics of the sensivity analysis of the variables time study of the business, financial and quality performance and montly cost, respectively.

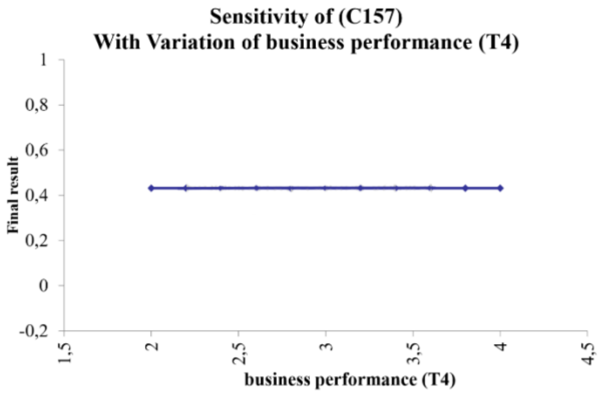


Figure 5: Sensitivity analysis of the time study of business performance

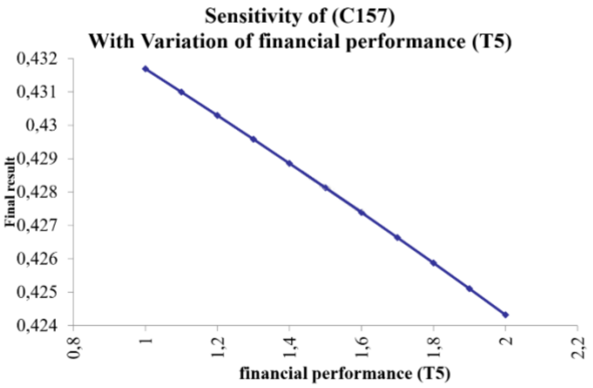


Figure 6: Sensitivity analysis of the time study of financial performance

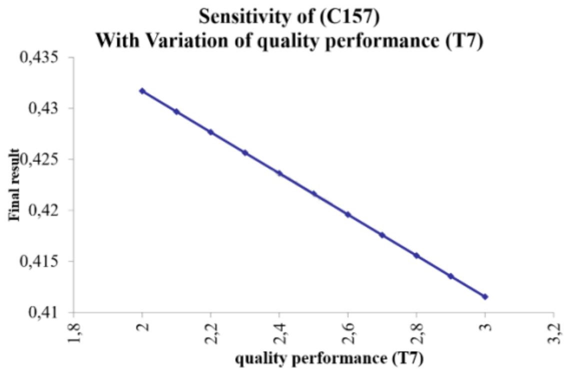


Figure 7: Sensitivity analysis of the time study of quality performance

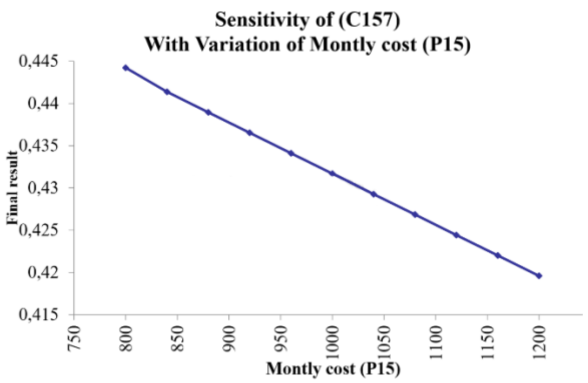


Figure 8: Sensitivity analysis of the cost per month of the study

Through the observation of these figures is possible to conclude that all varibles, except the variable related with the duration of study of the business performance, could affected the final global satisfaction.
Figure 5 present the tornado graph for this sensitivity analysis. This graphic shows that the most critical variable is the monthly cost, because it could present major changes in the final result.

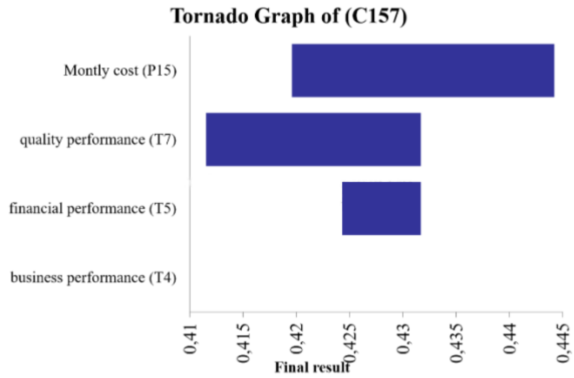


Figure 9: Tornado graphic of the Sensitivity analysis

## CONCLUSION

This study presented the application of multi-criteria decision analysis a context of an hyphotetical problem related with the impacts of the ISO 9001 implementation The method choosen was the weighted sum model. Addicionaly, a sensititive analysis was made.
The main conclusion is that multi-criteria decision analisys is a helpful methodology to aid the decision maker to choose the best alternative, considering his preferences. Through the use of these kind of models is possible to collect and summarize all the information nacessary/available in order to choose the best solution possible for the problem studied.
In the presented context, the best alternative for the problem on hand was the consideration of external motivation and the analysis of the financial and quality performance areas, simultaneously. It was also possible to conclude that the montly cost is the variable that could impose major changes in the final result.
The use of this method allowed to identify the need of the decision maker and the result dependency of his preferences, so different decision makers could led to a different optimal alternatives, according with his preferences.

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**ANNEX 1**

| Alternative | Motivation | Real Motivation | Probability Motivation | Areas | Probability Areas | Utility | Cost | Global Value |
|---|---|---|---|---|---|---|---|---|
| **1** | E | I | 20% | B | 0% | 4 | 3000 | 0,48 |
| **2** | E | I | 20% | B | 0% | 2 | 3000 | 0,26 |
| **3** | E | I | 20% | B | 100% | 1 | 3000 | 0,21 |
| **4** | E | I | 20% | F | 5% | 4 | 1000 | 0,52 |
| **5** | E | I | 20% | F | 50% | 2 | 1000 | 0,30 |
| **6** | E | I | 20% | F | 45% | 1 | 1000 | 0,25 |
| **7** | E | I | 20% | Q | 10% | 4 | 2000 | 0,50 |
| **8** | E | I | 20% | Q | 65% | 2 | 2000 | 0,28 |
| **9** | E | I | 20% | Q | 25% | 1 | 2000 | 0,23 |
| **10** | E | I | 20% | F+Q | 10% | 5 | 3000 | 0,67 |
| **11** | E | I | 20% | F+Q | 35% | 2 | 3000 | 0,26 |
| **12** | E | I | 20% | F+Q | 30% | 3 | 3000 | 0,35 |
| **13** | E | I | 20% | F+Q | 25% | 1 | 3000 | 0,21 |
| **14** | E | E | 80% | B | 10% | 4 | 3000 | 0,48 |
| **15** | E | E | 80% | B | 0% | 2 | 3000 | 0,26 |
| **16** | E | E | 80% | B | 90% | 1 | 3000 | 0,21 |
| **17** | E | E | 80% | F | 20% | 4 | 1000 | 0,52 |
| **18** | E | E | 80% | F | 50% | 2 | 1000 | 0,30 |
| **19** | E | E | 80% | F | 30% | 1 | 1000 | 0,25 |
| **20** | E | E | 80% | Q | 20% | 4 | 2000 | 0,50 |
| **21** | E | E | 80% | Q | 50% | 2 | 2000 | 0,28 |
| **22** | E | E | 80% | Q | 30% | 1 | 2000 | 0,23 |
| **23** | E | E | 80% | F+Q | 50% | 5 | 3000 | 0,67 |
| **24** | E | E | 80% | F+Q | 40% | 2 | 3000 | 0,26 |
| **25** | E | E | 80% | F+Q | 10% | 1 | 3000 | 0,21 |
| **26** | I | I | 60% | B | 0% | 4 | 3000 | 0,48 |
| **27** | I | I | 60% | B | 0% | 2 | 3000 | 0,26 |
| **28** | I | I | 60% | B | 100% | 1 | 3000 | 0,21 |
| **29** | I | I | 60% | F | 5% | 4 | 1000 | 0,52 |
| **30** | I | I | 60% | F | 50% | 2 | 1000 | 0,30 |
| **31** | I | I | 60% | F | 45% | 1 | 1000 | 0,25 |
| **32** | I | I | 60% | O | 10% | 4 | 6000 | 0,42 |
| **33** | I | I | 60% | O | 65% | 2 | 6000 | 0,20 |
| **34** | I | I | 60% | O | 25% | 1 | 6000 | 0,15 |
| **35** | I | I | 60% | Q | 10% | 4 | 2000 | 0,50 |
| **36** | I | I | 60% | Q | 65% | 2 | 2000 | 0,28 |
| **37** | I | I | 60% | Q | 25% | 1 | 2000 | 0,23 |
| **38** | I | I | 60% | F+Q | 10% | 5 | 3000 | 0,67 |
| **39** | I | I | 60% | F+Q | 50% | 2 | 3000 | 0,26 |
| **40** | I | I | 60% | F+Q | 30% | 3 | 3000 | 0,35 |
| **41** | I | I | 60% | F+Q | 10% | 1 | 3000 | 0,21 |
| **42** | I | I | 60% | F+O | 10% | 5 | 7000 | 0,59 |
| **43** | I | I | 60% | F+O | 50% | 2 | 7000 | 0,18 |
| **44** | I | I | 60% | F+O | 30% | 3 | 7000 | 0,27 |
| **45** | I | I | 60% | F+O | 10% | 1 | 7000 | 0,13 |
| **46** | I | I | 60% | O+Q | 25% | 5 | 8000 | 0,57 |
| **47** | I | I | 60% | O+Q | 40% | 2 | 8000 | 0,16 |
| **48** | I | I | 60% | O+Q | 30% | 3 | 8000 | 0,25 |
| **49** | I | I | 60% | O+Q | 5% | 1 | 8000 | 0,10 |
| **50** | I | I | 60% | F+O+Q | 30% | 6 | 9000 | 0,83 |
| **51** | I | I | 60% | F+O+Q | 25% | 2 | 9000 | 0,14 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **52** | **I** | **I** | **60%** | **F+O+Q** | **45%** | **3** | **9000** | **0,23** |
| **53** | I | I | 60% | F+O+Q | 0% | 1 | 9000 | 0,08 |
| **54** | I | E | 40% | B | 10% | 4 | 3000 | 0,48 |
| **55** | I | E | 40% | B | 0% | 2 | 3000 | 0,26 |
| **56** | I | E | 40% | B | 90% | 1 | 3000 | 0,21 |
| **57** | I | E | 40% | F | 20% | 4 | 1000 | 0,52 |
| **58** | I | E | 40% | F | 50% | 2 | 1000 | 0,30 |
| **59** | I | E | 40% | F | 30% | 1 | 1000 | 0,25 |
| **60** | I | E | 40% | O | 0% | 4 | 6000 | 0,42 |
| **61** | I | E | 40% | O | 0% | 2 | 6000 | 0,20 |
| **62** | I | E | 40% | O | 100% | 1 | 6000 | 0,15 |
| **63** | I | E | 40% | Q | 20% | 4 | 2000 | 0,50 |
| **64** | I | E | 40% | Q | 50% | 2 | 2000 | 0,28 |
| **65** | I | E | 40% | Q | 30% | 1 | 2000 | 0,23 |
| **66** | I | E | 40% | F+Q | 50% | 5 | 3000 | 0,67 |
| **67** | I | E | 40% | F+Q | 40% | 2 | 3000 | 0,26 |
| **69** | I | E | 40% | F+Q | 10% | 1 | 3000 | 0,21 |
| **70** | I | E | 40% | F+O | 0% | 5 | 7000 | 0,59 |
| **71** | I | E | 40% | F+O | 70% | 2 | 7000 | 0,18 |
| **73** | I | E | 40% | F+O | 30% | 1 | 7000 | 0,13 |
| **74** | I | E | 40% | O+Q | 0% | 5 | 8000 | 0,57 |
| **75** | I | E | 40% | O+Q | 70% | 2 | 8000 | 0,16 |
| **77** | I | E | 40% | O+Q | 30% | 1 | 8000 | 0,10 |
| **78** | I | E | 40% | F+O+Q | 0% | 6 | 9000 | 0,83 |
| **79** | I | E | 40% | F+O+Q | 40% | 2 | 9000 | 0,14 |
| **80** | I | E | 40% | F+O+Q | 50% | 3 | 9000 | 0,23 |
| **81** | I | E | 40% | F+O+Q | 10% | 1 | 9000 | 0,08 |

**Legend:** E – External Motivation; I – Internal Motivation; B – *Business performance*; F – *Financial performance*; Q – *Quality performance*; O – *Operational performance*; F+Q – *Financial/Quality performance*; F+O – *Financial/Operational performance*; O+Q – *Operational/Quality performance*; F+O+Q – *Financial/Operational/Quality performance*; the utility values presented are based on the table 1.