THE DECISION PROCESS AS BASIS FOR A NEW SYSTEMATIZATION OF THE INFORMATIONAL DESIGN STAGE TO INDUSTRIAL PRODUCTS

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Abstract. *This paper includes the initial stages of the products development process - more specifically the stage known as Informational Design - considered to be fundamental to the success of a new product on the market. The complicating factor is that during this development stage, the different specifications and attributes of the product are defined by dealing with a multitude of choice's criteria, based on customer needs. Thus, this research aims to propose a new structure of the Informational Design stage, adapting it to the methods and tools offered by the methodologies of the decision dealing with multiple criteria problems in order to contribute to improving the practice of project in its initial stages. With this objective, it has developed a multicriteria model along the lines of Reference Unified Model by Rozenfeld et al (2006), to propose methods, tools and supporting documentation appropriate to the achievement of each activity. Improvements and the values that the practical application of the multicriteria model adds to the Product Development Process were discussed through a case for a commercial product project, whose development had the participation of this paper's author.*

Keywords*: Product Development Process, Informational Design, Decision Process*

1. INTRODUCTION

In relation to the process of gathering and analysing the requirements of the customers, it is possible to notice in the literature an usual approach that involves the main decisions made during the project. Usually these actions are organized in a project's phase named 'Informational Design'. Several authors, like Pugh (1990), Roozenburg and Eekels (1995), Baxter (1995), Pahl and Beitz (1996), Fonseca (2000), Otto and Wood (2001), Rozenfeld et al (2006), among others, in a direct or indirect way, propose the following main actions from Informational Design stage: 'customers definition'; 'customers requirements identification'; 'customers requirements conversion in product requirements' and 'project specifications achievement'. It´s relevant here to highlight that the final result of these procedures are the project specifications, which have two main objectives: to guide the following steps of product development and to serve as a criteria for the decisions taken along the project (NICKEL, 2009).

Recently, have been developed studies which aim formalize and systematize the decision process, of which already emerged methodologies directed to work with problems that evolve multiple criteria choice. From Operational Research has been developed the multicriteria approach that, among its many scientific applications, also may be useful in front of complex project decisions. The main goal of this paper is to show the construction of a model that will serve as reference, about its multicriteria approach and the focus in the decision making process, to the products development stage, named Informational Design. With this new stage systematization, adapting it to the methods and tools proposed by the decision methodologies which deal with multi criteria problems, the aim is to contribute to the improvement of the project practice in its early stages. The model will be developed and described, step by step, using as background the Unified Reference Model, of Rozenfeld et al (2006), one of the more late and complete of the researched literature.

2. MULTICRITERIA MODEL CONSTRUCTION

Before showing the construction of the model in question it's important to make clear the way the propose will be graphically showed in each one of the topics that follow. The representation is organized with basis in Keeney's means-ends network. As Figure 1 illustrates, the means to achieve the activities are the tasks. The means to achieve the tasks are the methods, tools and supporting documents which can be obtained through the literature.

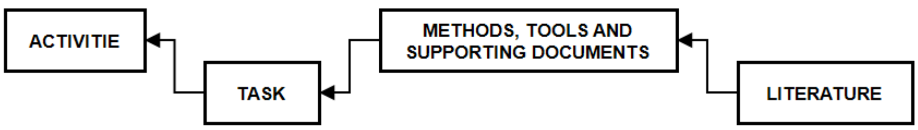


Figure 1. Schematic representation of multicriteria model

It must be noticed that the representation of the arrows is from the boxes which contains the means description pointing to the boxes which contains the ends description, in this case, right to left. Besides, the indicated literature was summarized to basic and fundamental authors, to each presented concept. In extrapolating Figure 1 content, one can say that the end (or objective) common for all activities contemplated in this chapter is to meet the Informational Design stage. Following the same reasoning, that stage is one of the means (along with the others generic stages of Project Planning, Conceptual Design, Detailed Design, Production Preparation and Product Release) to achieve a product's full development.

2.1. To identify the customers' requirements of the product

With basis in these conventions, Figure 2 describes the multicriteria model of the Informational Design activity 'To identify the customers' requirements of the product'. As showed, that activity is achieved by four tasks: 'To gather the customers' needs in each phase of the life cycle'; 'To group and classify the needs'; 'To define customers requirements' and; 'To value customers requirements'. In the beginning of the first task, the information that is already available, obtained in the previous activities, is: product scope statement; product life cycle and; product customers. On the other hand, the information generated at the end of the activity will be the customers' requirements.

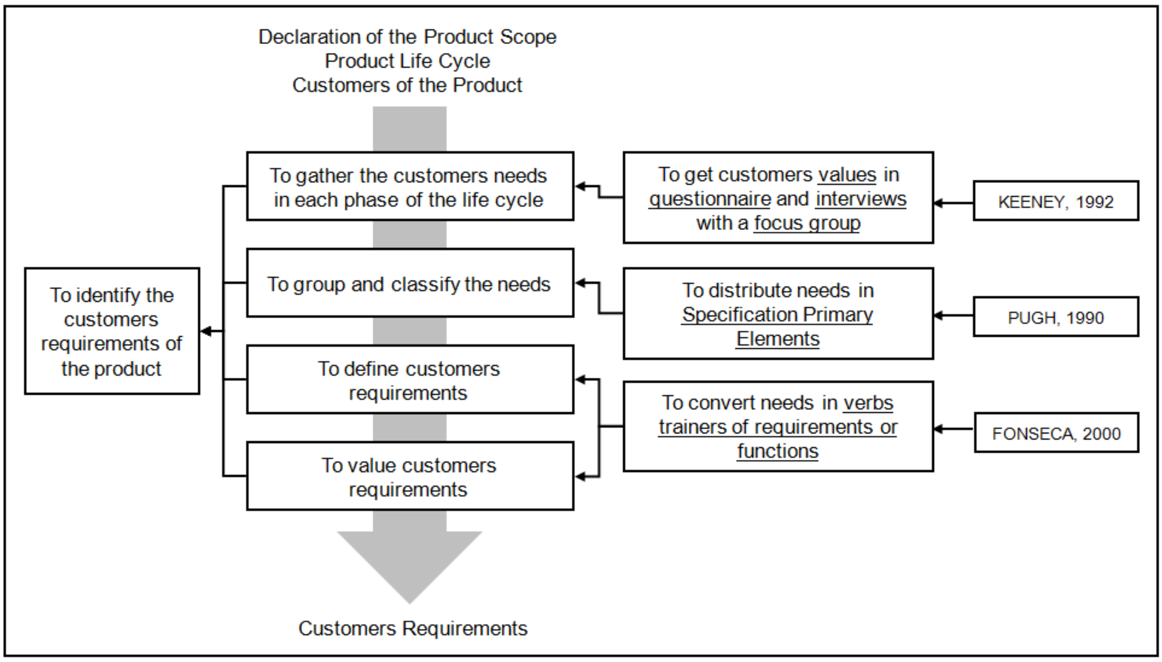


Figure 2. 'To identify the customers' requirements of the product' activity, with multicriteria approach

For the first task 'To gather the customers' needs in each phase of the life cycle', it was proposed to obtain the customers values, because, according to Keeney (1992, p. 1), the alternatives to solve a problem "are relevant just because they are means to achieve their values. So, your first thought shall be focused in values and, later, in alternatives to achieve them". So that the customers' values, showed as needs, are the foundations of Informational Design. However, how to obtain so subjective information from a so large public like consumer's market? In a pilot project, using MCDA methodology, recently published, was made an experiment in gathering the needs of a symbol character, an individual who represents the target-public of the concerned product. Yet the work's final suggestion about this subject was to applied questionnaires and interviews in a scenario with several purchasing decision persons, because this procedure would increase the chances of the target-public preferences being better represented (BALBIM et al, 2008a; BALBIM et al, 2008b).

Therefore, the proposal for this needs survey through the values is the implementation of a focus group. The focus group involves the assortment of a five to nine consumer´s group and is performed in a controlled environment, through a group dynamics where the customers are stimulated to react to the products and their behavior, comments and suggestions are evaluated (AAKER, KUMAR and DAY, 2001). The goal of this qualitative research, according to Baxter (1995, p. 167), is to achieve the deep perception of a few consumers market needs. The author also suggests the approximate number of five people to the group.

When a wide enough set of needs was already obtained, then comes the second task, that is, to group and classify that needs, for the project team can verify similar needs and to erase the replicates and less relevant needs to the project. As seen in Figure 2, the proposed mean to achieve that task is to distribute the needs in Specification Primary Elements

(PUGH, 1990). That elements must be taken into account when the needs sorting because, according to the author, they act like a mantle involving the project activities central core.

Once accomplished the grouping, analysis and classification of the needs, they must be rewritten as customers requirements due to the fact that they were first described according to the customers language. That refinement, as the activity third task, will allow the project team to work better with the obtained information, in a project language, linking the requirements with aspects as: functional performance, human factors, properties, space, reliability, life cycle, resources and manufacturing (ROZENFELD et al, 2006, p. 219).

According to Fonseca (2000, p.59), an easy way to convert the needs in customers' requirements, is the following: all user requirement is (1) a short phrase composed by the verbs to be or to have, followed by one or more substantives, or (2) a phrase composed by a verb that is not to be or to have, followed by one or more substantives denoting, in this case, a possible product function.

Finally, the activity of identify the product customers requirements is completed with the task 'to value the customers requirements'. It's fundamental to highlight that this task accomplishment is unnecessary to the proposed model, since the QFD usual tool will be deleted in this work. This valuation is just needed to the insertion of customers' preferences degrees in the house of quality matrix and, despite the task had been maintained in the graphic scheme in order to keep the original arrangement, it doesn't offers greatest benefits to the multicriteria model in focus.

2.2. To define product project requirements

The graphic scheme, or mind map, of the Informational Design second activity contemplated with the multicriteria approach can be seen in Figure 3. It's 'to define product project requirements'. There is that the main input to this activity is the 'customer requirements' obtained in the previous activity. In the other end, the main output, or delivery, are the 'product requirements'.

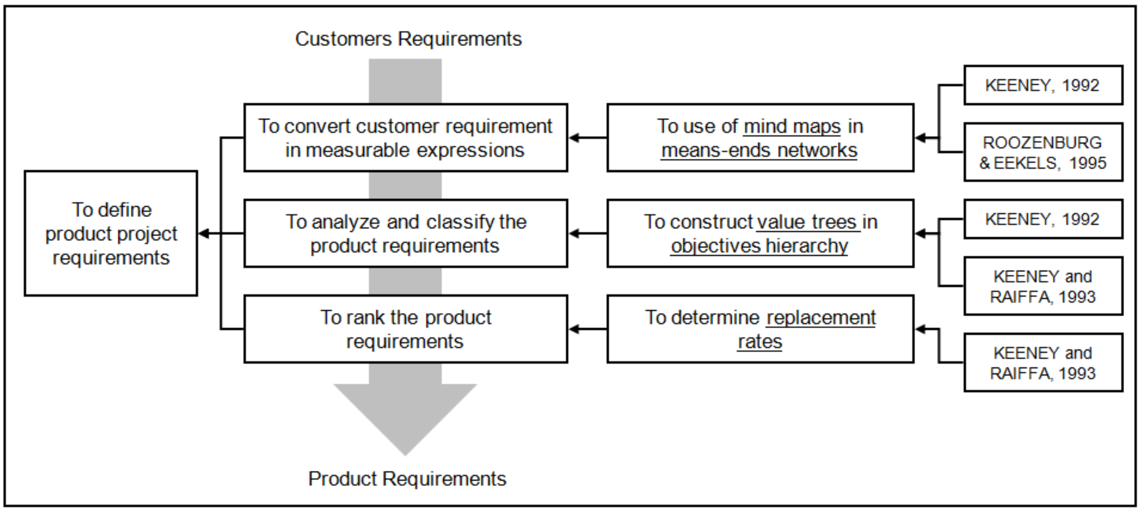


Figure 3. Activity 'to define product project requirements' with multicriteria approach

The method used in this model to accomplish the first task, that is, to convert customer requirements in measurable expressions is proposed by Roozenburg and Eekels (1995), based in Keeney (1992) studies. This is precisely the utilization of mind maps in means-ends network. A means-ends network is a set of objectives, each one of them can be seen as a mean to achieve an end, or a cause of an effect. This way, the low levels of the map usually are more operational objectives and easier to measure (ROOZENBURG and EEKELS, 1995, p. 141). Figure 3 is an illustration of a means-ends network structure.

Therefore, the means-ends network method has as one of most important results, the primary objectives achievement, or the operational ones, that which occasionally contribute to a global problem solution, through small local solutions. For example, the objective of 'properly maintain vehicles' is obtained by other three smaller goals, more specifics: 'to have reasonable laws', 'to enforce the law' and 'to educate about security' (KEENEY, 1992, p. 70). Applied to an industrial product, this method would be especially true to obtaining various product attributes and requirements from the customer requirements. The product requirements would be the means and the correlated customer requirement, the end to be achieved.

Through the mind maps analysis, so far obtained in the project, can be started the activity second task, that is 'to analyze and classify the product requirements'. To this end, is proposed the model structuring through the "value trees" construction in "objectives hierarchy" (KEENEY, 1992; GOODWIN and WRIGHT, 1998).

To Keeney (1992, p.69), the objectives structuring process results in a deeper and more precise knowledge about of what shall be concerned in the decision context. The structuring helps to clarify the decision context and to define the set of fundamental objectives. This leads to a clearer distinction between the fundamental objectives and means objectives. Keeney and Raiffa (1993) suggest five criteria which can be used to judge the value tree, aiming its correct construction: completeness, operationality, decomposability, absence of redundancy and minimum size. With respect to a value tree constituents objectives, Keeney (1992) classify them in "fundamental objectives" and "means objectives", following a logic similar to the existing in the means-ends network structure. Besides, Keeney (1992, p. 82) guides for that the objectives used in a formal model have the following features: be essential; controllable; measurable; operational; can be decomposed; not redundant; concise and; understandable.

The third and last task of the activity in focus concerns to rank the product requirements, already obtained with the mind maps and organized in the value tree. This objective can be reached with the determination of the "replacement rates", as showed in Figure 4. To Keeney and Raiffa (1993, p. 83) the replacement rate concept is the negative reciprocal of indifference curve inclination. In simple terms is the compensation that occurs when percentage values are attributed to each one of the value tree objectives. As exemplified in Figure 4 value tree, related to the fictional project model of a paper clip, the sum of the rates belonging to the relative objectives must ever be equal to 100 %.

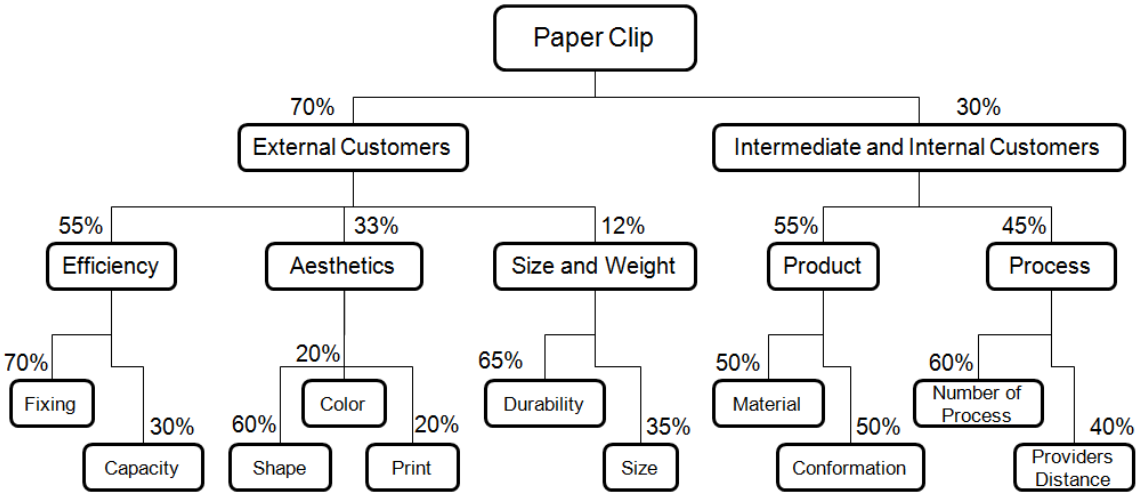


Figure 4. Value tree and replacement rates

The replacement rates can be directly measured. However, to facilitate de distribution of values for three or more relative objectives, is suggested the use of a systematic procedure in this project step. One of these procedures is the diagram of Mudge, showed as example in Figure 5, where de means objectives to achieve an improved "aesthetics" to the paper clip are dimensioned. The advantage of using the diagram of Mudge is that it exempts the use of commercial software.

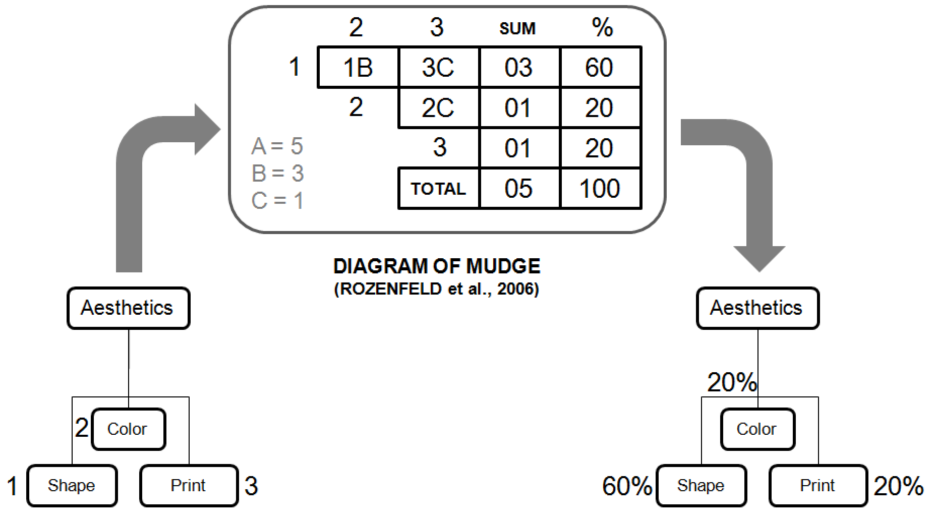


Figure 5. Diagram of Mudge

In this diagram the valuation is made by the comparison of the objectives in pairs and obtaining a ranking, or objectives hierarchy and how much each one of them is more or less important to the customer. During the comparisons are made the next questions: "What requirement is more important to the product success? How more important is this requirement?" (ROZENFELD et al, 2006, p. 222). Specifically in Figure 5, the number/letter blend in the central fields represents what objective is prevalent an its importance intensity. For example, where appears "1B", soon in the first field, means that objective 1 prevails over objective 2 with an intensity of 3 (B) according to the legend. In the two last columns is obtained the objectives ranking, in other words, their respective degrees of importance. Objective 1 is the most important, with a replacement rate of 60%, while objectives 2 and 3 have the same degree of importance for the purchase decision, 20% each, according to Figure 5.

2.3. To define product target-specifications

The third and last activity to be proposed to this multicriteria approach model is represented in Figure 6. It is 'to define product target-specifications' activity. There is again that the key information input to this activity are the 'product requirements', obtained in the previous activity, while the result, or delivery, is the 'product target-specifications' list.

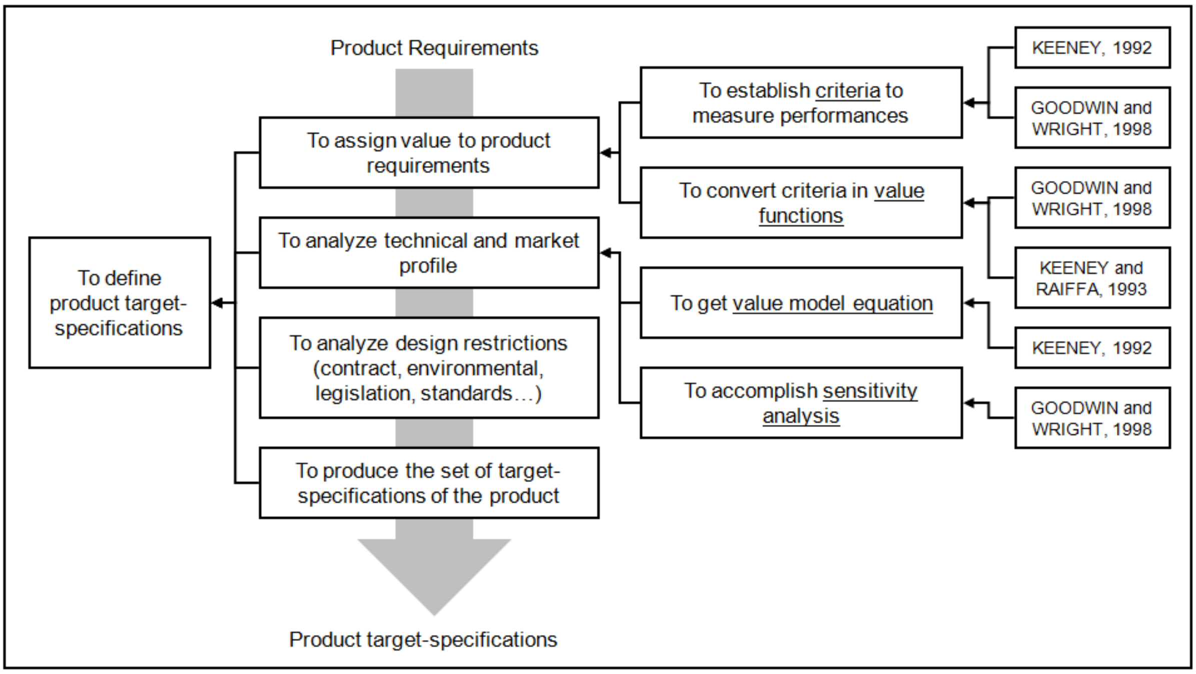


Figure 6. Activity 'To define product target-specifications' with multicriteria approach

After the whole structure, or objects hierarchy, is defined in the previous activity, as well the model replacement rates determination, the first task of the 'to define product target-specifications' activity is 'to assign value to product requirements'. For this purpose, there are two objectives as means to make it. The first one involves 'to establish criteria to measure performances'.

More than objectives, a value tree has "attributes" (KEENEY and RAIFFA, 1993; GOODWIN and WRIGHT, 1998), also called "criteria" (KEENEY, 1992), in their low level. These criteria are obtained through the analysis of the chain of means and ends, which were built in the first task of the phase and then organized in the objectives hierarchy, or value trees.

The criteria are established to measure the most operational objectives performance, the ones in the model end. As explained, the thought in search of the means to fulfill the customers' needs leads to certain characteristics the product should have. These characteristics, finally, will be called "criteria" in this paper.

With the objective to improve the understanding about what is a 'criteria', as defined in this paper, one should imagine again that a consumer wish to purchase a paper clip. One of his needs is that the clip can hold several sheets of paper at the same time. The product requirement would be related to the clip capability while the criteria used to measure this performance would be the maximum amount of paper sheets that could be hold by a single clip. The customer preferences, to this example, are organized in the criteria showed in Figure 7.

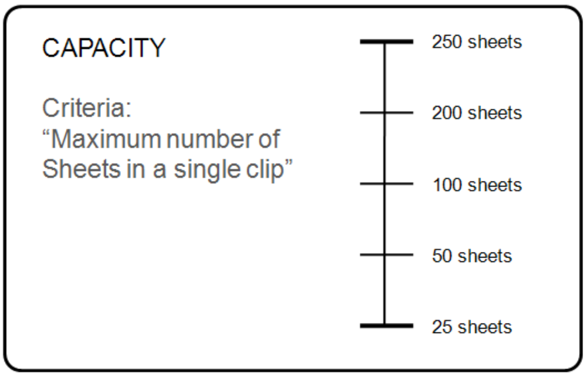


Figure 7. Building of a criteria, or attribute

In the presented figure, all performance levels are acceptable for the customer, though the higher in the graphic representation are the preferable. The important is that the criteria attribution to measure the objectives always requires assessments of value (KEENEY, 1992, p. 100). Accordingly, these assessments of value can lead to important insights and, often, alternatives to solve important parts of a decision problem. This is especially true in product project problems, when the designers are in front of multiple options of choice and the doubts about some of the specifications implementation are frequent.

After the entire model criteria was set, the second procedure to the task of 'to assign value to product requirements' (see Figure 6) is to convert the obtained criteria in "value functions" (KEENEY and RAIFFA, 1993; GOODWIN and WRIGHT, 1998). Therefore, once certain the model criteria, the decision maker then should encode his preferences to this consequences, in cardinal numbers of utility. To Keeney and Raiffa (1993, p. 6), this measure not only reflects the decision maker ordinal rankings to different consequences, as also indicates his relatives preferences to choose over this consequences.

In other words, in the previous procedure, the development team, together with the focus group, had determined the preferential order for the options or potential actions of a certain criteria. However, it is not possible to yet how each option is desired, compared with the others, ie, it is not possible to know the importance degree that some choice option implementation offers to the model and to the product project. This is exactly the value function concept. In mathematical terms "a function 'v', when associated to a real number 'v(x)' for each point 'x' in a valuation space, it is a value function", representing the decision maker preference structure (KEENEY and RAIFFA, 1993, p. 80).

To facilitate understanding, Figure 8 illustrates the criteria conversion already exposed in Figure 7 for a value function.

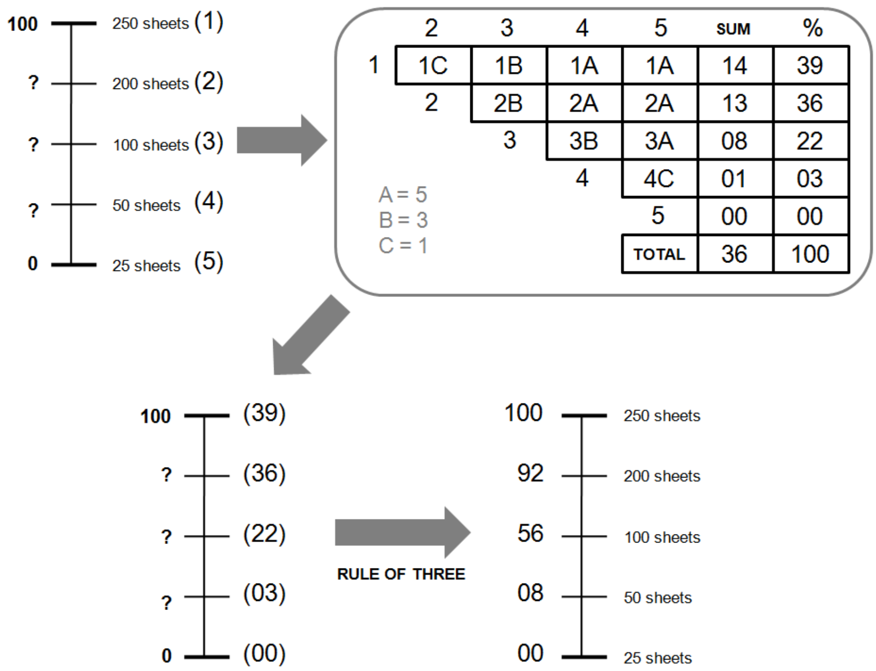
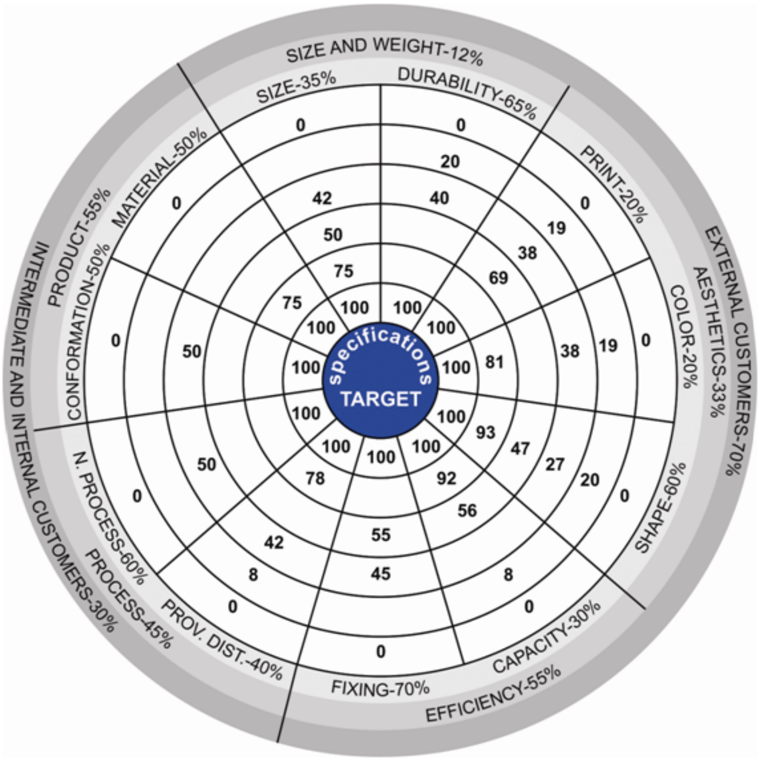


Figure 8. Conversion of a criteria to a value function

It is noted in the figure that to the criteria highest level is assigned number '100', while to the lowest level is assigned number '0'. This will become a convention in this paper, to simplify the calculations, following the model of Goodwin and Wright (1998). Another detail, clearly in Figure 8 is that, to obtain the intermediate levels between '0' and '100', is proposed again the use of the Diagram of Mudge. So, to finish the conversion procedure, applying a simple 'rule of three' over the obtained values in the diagram will generate the desired relative scale.

After all model value functions were obtained, adding them up to the replacement rates values is possible to obtain the project "value model" (KEENEY, 1992), expressed as a mathematical equation. To this paper, the equation result will be called Requirements Accomplishment Index (RAI), that will indicate how a particular design solution or a competing product meets the project requirements and, consequently, the customer needs. This model will allow, finally, to made the next task of the activity in focus, described in Figure 6, that is 'to analyze technical and market profile' for the developing product. The paper clip case value model, as the equation which explained it, is showed as example in Figure 9.



REQUIREMENTS ACCOMPLISHMENT INDEX =

$$0.7 \times \{0.55 \times [0.7 \times (0;\ 45;\ 55 \text{ or } 100) + 0.3 \times (0;\ 8;\ 56;\ 92 \text{ or } 100)] + 0.33 \times [0.6 \times (0;\ 20;\ 27;\ 47;\ 93 \text{ or } 100) + 0.2 \times (0;\ 19;\ 38;\ 81 \text{ or } 100) + 0.2 \times (0;\ 19;\ 38;\ 69 \text{ or } 100)] + 0.12 \times [0.65 \times (0;\ 20;\ 40 \text{ or } 100) + 0.35 \times (0;\ 42;\ 50;\ 75 \text{ or } 100)]\} + 0.3 \times \{0.55 \times [0.5 \times (0;\ 75 \text{ or } 100) + 0.5 \times (0;\ 50 \text{ or } 100)] + 0.45 \times [0.6 \times (0;\ 50 \text{ or } 100) + 0.4 \times (0;\ 8;\ 42;\ 78 \text{ or } 100)]\}$$

Figure 9. Value model equation

The graphic representation suggests the interest, both from the users as the producing company, to implement the more target centralized levels. The goal is to hit the most desired specifications by the external, intermediary and internal customers. A model like this, representing, as closely as possible, the customers point of view to the developing product, will be very useful to competing products analysis, as an example, indicating what the current market performance, or status quo (KEENEY, 1992; GOODWIN and WRIGHT, 1998).

Continuing with the technical and market profile, comes to the last support method to the developed multicriteria model. Now suggests the implementation of the model 'sensitivity analysis'. To Goodwin and Wright (1998, p. 35) "the sensitivity analysis is used to examine how robust is an alternative choice in the changes of the analysis used values". This analysis can also be graphically represented, making it much easier to visualize the mathematical balance, or "tradeoffs" (KEENEY, 1992), existing in the developed value model. A sensitivity analysis illustration is showed in Figure 10.

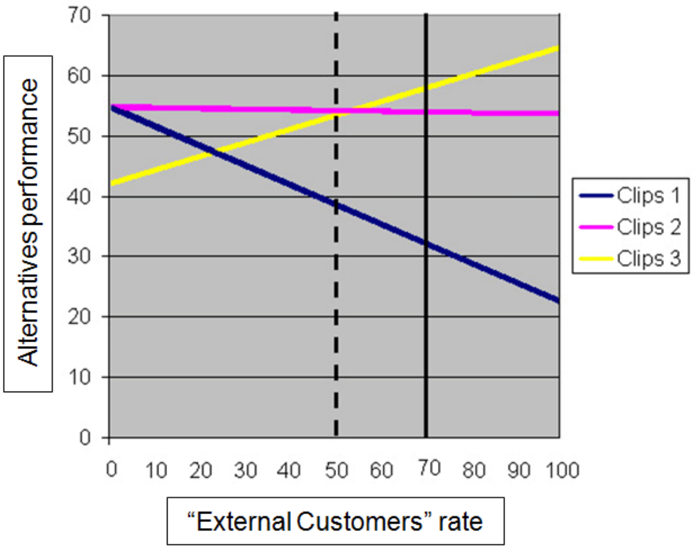


Figure 10. Sensitivity Analysis

In the example, three different types of paper clips, sold in the market, were compared, based in their performances to the value model already shown in Figure 9. The sensitivity analysis is now being held with the focus in the objective "External Customers" replacement rate, which is currently 70 %, indicated in the graph as a vertical, continuous line. For these values, the "clip 3" is demonstrating the best overall performance. However, if the objective replacement rate is reduced to 50 % of importance, or less, is "clip 2" which has the best performance, as represented by a dashed vertical line.

Finally, based on this analysis, the model is refined and, with the following task, that is 'to analyze product design restrictions (contract, environmental, legislation, standards…)', presented in Figure 6, is possible to gather all the knowledge built up to this project moment and to produce the set of target-specifications of the product, the main objective of Products Development Process Informational Design stage.

3. DISCUSSION OF RESULTS

The main purpose of this topic is the discussion about the benefits that the multicriteria approach and the focus on decision-making offer for the product project first steps, specifically the Informational Design stage. For this purpose, the model was applied in developing a commercial product with a company of technological base in the state of Santa Catarina, Brazil (NICKEL, 2009). The proposal is justified by the aspects that add value to development but not yet covered with other PDP traditional methods and tools.

As a first benefit, using focus group support facilitates the needs attainment. Another conclusion was that the customer requirements which are relatives, i.e., that have similar objectives, could be better analyzed when grouped in the Specification Primary Elements and in the mind maps.

Using mind maps in means-ends network, and the logic existing in that tool, could be obtained more easily the product requirements from the customer requirements. Besides, the other elements that compose the mind maps enabled a better understanding about what customers wanted to say with the needs expressed in the research and the main objectives that the product should attend. This saved time and effort in developing.

Through the construction of the value tree with the project objectives hierarchy, one could explain and better understand the value (replacement rates) assigned by the customers to the various requirements arising in the development. The model 'tradeoffs' , i.e., the compensation percentage that occur between the requirements, can only be observed in tools like the value tree, an advantage over QFD or other traditional methods.

With the development of criteria and their conversion to value functions, the target-specifications were not merely a static value or simply a range of values. This tool could explain there are levels of performance better than others and that, if achieved, will contribute even more to development success, specially the critics requirements, ie, those valued to a greater extent. Also was noticed in the case study, that the elaboration of value functions stimulates creativity, what led even to deeper interventions in the product, anticipating some solutions that are normally developed only in the conceptual design, through the generation of alternatives.

The 'Requirements Care Index', proposed in this paper, obtained using the value model equation, aimed the market status analysis and how much competing products or the company portfolio are filling the developing project specific needs. Finally, the study suggested the usefulness of multicriteria model, also developed to support the decision already in the Conceptual Design stage of the case study, when it was possible to perform a comparative analysis between two alternatives generated for the project. The final decision was guided by the analysis of which generated concept had a more satisfactory way of meeting the requirements considered essential for the project. The sensitivity analysis of the model assumed a crucial role by facilitating the visualization of losses and gains that each alternative would change as the value assigned by each group of customers. These, finally, helped further the company and the development team to justify the decision for this project in particular.

4. CONCLUSIONS

In summary, the immediate conclusion that this work could explain was that the stage of Informational Design is the most critical of the products development process on the complexity of its implementation and the level of importance of design decisions taken. It is no surprise, therefore, that a product developed without deep and frequently consultation with their customers has the risk of not obtaining increased commercial success, regardless of how competent is the realization of other stages of project.

Therefore, it is hoped that this paper has helped to systematize the activities of collection, analysis and organization of information obtained during the Informational Design stage, when considering the treatment of such information as what it really is: a business process that involves multiple selection criteria, and uncertainty in the decisions that must be supported with existing best practices.

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6. RESPONSIBILITY NOTICE

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