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MULTI CRITERIA DECISION MAKING IN PRODUCT PLATFORM DEVELOPMENT AND EVALUATION

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Key words: decision making process, product platform development, analytic hierarchy process, cooling generator

1. Introduction

As the global business environment becomes more intense, competitive advantage for enterprises depends on being able to produce products with increased quality, reduced cost and shorter times-to-market [Hicks, Cully, Allen, Mullineaux, 2002]. Collaborative product development has become a significant strategy employed to reduce technology risk and development time, as well as to attack a new marketplace [Hung, Kao, Chu , 2007]. Individuals, corporations and governments [Saaty, 2007], constantly face the extremely complex problem of ordering and prioritizing their numerous decisions according to urgency and importance. They need to sequence expenditures and allocate scarce resources to optimize the returns on their investments over time. Prioritization requires general and diverse economic, social, political, environmental, cultural and other criteria that reach beyond the familiar process of deciding on the best alternative in making a single decision. Decisions about decisions are more difficult as the best choice for each particular decision is often unknown requiring a large amount of time and resources to determine.

The paper describes the application of two methods, and the proposed framework, with which we want to achieve optimal choice platform products, combining the following methods: Modular Function Deployment (MFD) (my previous work) and evaluation using of multicriteria decision making process, based on the method of Analytic Hierarchy Process (AHP). Here we applied computer tools "SuperDecisions" for creating a hierarchical model of AHP decision making. With this work we want to improve and accelerate the development of product platform (in this case on the example of cooling generator with air-cooled condenser with axial fan and for outdoor position of installation).

2. Previous work

Decision framework for product platform development and evaluation (see Figure 1.) shows the entire spectrum of product realization according to the concept of design domains [Suh, 2001]. Based on such a holistic view [Jiao, Simpson, Siddique, 2007], product family design and development encompasses consecutively five domains, namely the customer, functional, physical, process and logistics domains. Product family decision making process involves a series of "what-how" mappings between these domains.

The customer domain is characterized by a set of customer needs (CNs) representing segmentation of markets that demand for product families and triggering downstream product family design mappings in a cascading manner. The CNs are first translated into functional requirements (FRs) in the functional domain, in which designers take into account engineering concerns and elaborate these requirements based on available product technologies. The mapping between the customer and functional domains constitutes the front-end issues associated with developing product families. Such a product family definition task is always carried out within an existing product portfolio and manifests itself through these common practices of order configuration and sales force automation. Product family design solutions are generated in the physical domain by mapping FRs to design parameters (DPs) based on the shared product platform.

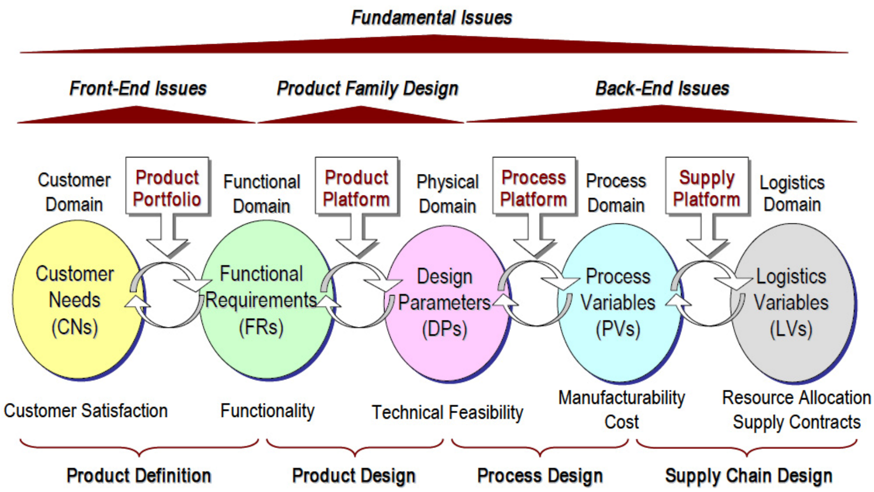

Figure 1. A holistic view of product family design and development

This stage involves typical decisions regarding product family design and configuration. A the front-end, the product portfolio articulates detailed achievement of customer satisfaction in the customer domain in the form of specifications of functionality in the functional domain. On the hand, the main focus of platform-based product family design is the technical feasibility of DPs in terms of fulfilling the specified functionality. The back-end issues associated with product families involve the process and logistics domains, which are characterized by process variables (PVs) and logistics variables (LVs) respectively. The mapping from DPs to PVs entails the process design task, whiuch must generate manufacturing and production planning within existing process capabilities and utilize repetitions in tooling, setup, equipment, routings etc. Corresponding to a product platform, production processes can be organized as a process platform in the form of standard routings, thus facilitating production configuration for diverse product family design solutions [Jiao, 2000].

3. Proposed framework for product platform development and evaluation

In this section, I describing proposed framework for product platform development and evaluation. Framework contains of combining two methods (see Figure 2.): Modular Function Deployment (MFD) and the analytic hierarchy process (AHP) for muticriteria decision making.

3.1 Modular Function Deployment (MFD)

The Modular Function Deployment (MFD) is a systematic method and procedure for development of modular products, consisting of five main steps [Erixon, 1998]. The method analyzes the functional requirements for a product and determines the technical solution and modular concept. MFD was already done in my previous work [Osman, Bojčetić, Marjanović, 2008]. In definition of potential modules, we also use the Modular Indication Matrix (MIM), testing the interrelations between the cause of modularity and the technical solution. MIM also ensures a mechanism for researching the possibilities of integrating multiple functions into individual modules. MFD consists of the following steps:

1. Clarify customer requirements,
2. Technical solutions,
3. Define possible modules,
4. Evaluate concepts,
5. Improve each module.

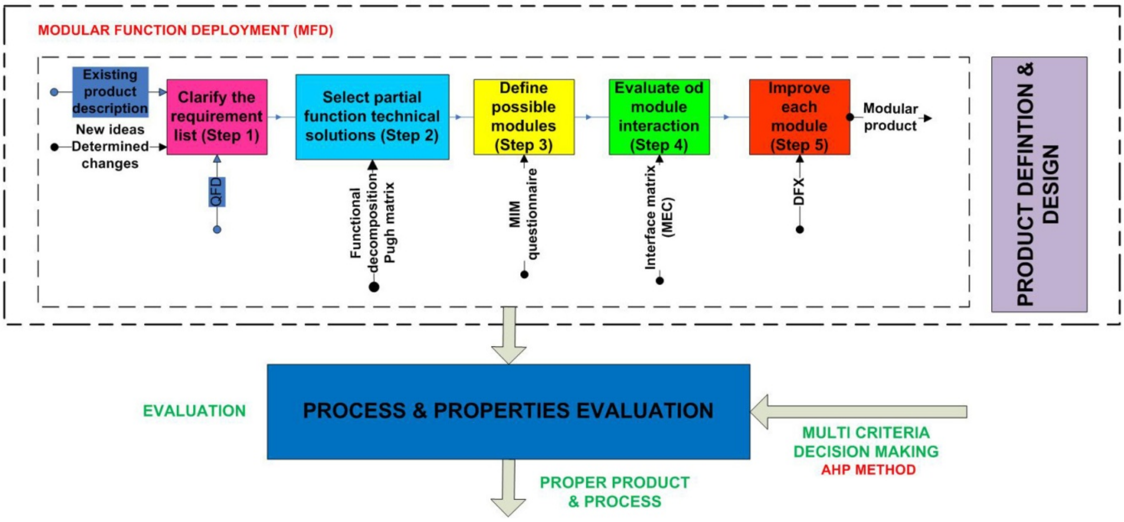

Figure 2. Proposed framework for product platform development and evaluation

3.2 Multi criteria decision making

Multi-criteria decision analysis (MCDA), sometimes called multi-criteria decision making (MCDM), [Saaty, 2005] is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process. Unlike methods that assume the availability of measurements, measurements in MCDA are derived or interpreted subjectively as indicators of the strength of various preferences. Preferences differ from decision maker to decision maker, so the outcome depends on who is making the decision and what their goals and preferences are. Depended on the certainty of alternatives [Clemen, 1996], MCDA is classified to multi-objective decision analysis (MODA) and multi-attribute decision analysis (MADA). MODA discusses the decision making of unknown alternatives; it can come out an optimum solution via assessment of multiple objective constraints. On the other hand, MADA discusses about known decision alternatives, to select the most suitable solution through measurement of multiple attributes.

3.2.1 The Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision, the AHP helps the decision makers find the one that best suits their needs and their understanding of the problem. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations [Saaty, 2008].

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making

techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.
The procedure for using the AHP [Saaty, 1999] can be summarized as:

1. Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives.
2. Establish priorities among the elements of the hierarchy by making a series of judgments based on pair wise comparisons of the elements. For example, when comparing potential real-estate purchases, the investors might say they prefer location over price and price over timing.
3. Synthesize these judgments to yield a set of overall priorities for the hierarchy. This would combine the investors' judgments about location, price and timing for properties A, B, C, and D into overall priorities for each property.
4. Check the consistency of the judgments.
5. Come to a final decision based on the results of this process.

4. Super Decisions

The Super Decisions software is used for decision-making with dependence and feedback (it implements the Analytic Network Process, ANP, with many additions). Program was developed by Dr. Thomas Saaty and was written by the ANP Team, working for the Creative Decisions Foundation. Such problems often occur in real life. Super Decisions extends the Analytic Hierarchy Process (AHP) that uses the same fundamental prioritization process based on deriving priorities through judgments on pairs of elements or from direct measurements. In the AHP the elements are arranged in a hierarchic decision structure while the ANP uses one or more flat networks of clusters that contain the elements. Most decision-making methods assume independence between the criteria of a decision and the alternatives of that decision, or simply among the criteria or among the alternatives themselves.

5. Product platform development

The proposed framework described in section 3. here will be shown in example of development of cooling generator with air-cooled condenser with axial fan and for outdoor position of installation.

5.1 Product platform planning

Based on my previous work (Osman, Bojčetić, Marjanović, 2008) modules and components are already found in Modular Indication Matrix and Interface Matrix.

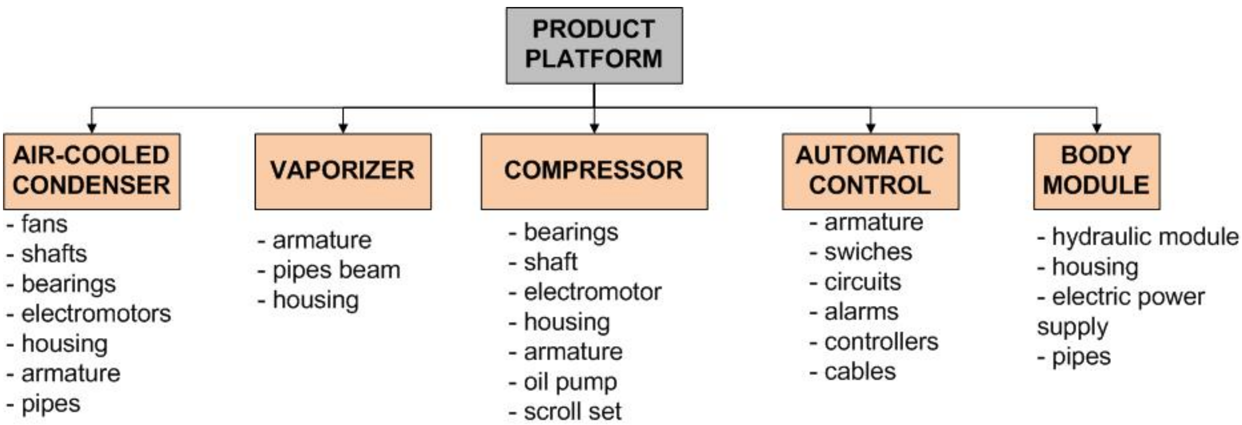

Figure 3. Platform architecture for cooling generator with air-cooled condenser

5.2 Product family planning

Next step in this procedure is to construct product architecture for each family. Market segregation grid is based on size of the family (which depends on power of cooling and heating capacity). Here we can obtain three different models of these cooling generators:

- With smaller power of capacity (cooling capacity 9-25 kW; heating capacity 12 – 27 kW),
- With medium power of capacity (cooling capacity 35 – 60 kW; heating capacity 37 – 55 kW),
- With large power of capacity (cooling capacity 73 – 125 kW; heating capacity 70-115 kW).

5.3 Evaluation

When we generate design alternatives with all information about their costing and scheduling, then we are doing evaluation, select a proper solution for a desired product. The evaluation criteria basically assess the satisfaction of the business intentions and customer requirements simultaneously, as well as the requirements of design (product and process) and manufacturing. Usually they are related to quality, delivery time, cost and flexibility (see Figure 4.).The objectives in the fundamental objectives hierarchy list all aspects of consequences that are important in the context of decision. The relative desirability of contending alternatives is measured solely by the degree of achievement of these objectives.

Here we use a software tool “Super Decisions” (see section 4) to build AHP Hierarchical Decision Model. Using these criteria on our design alternatives, we can set the desired objectives to achieve maximum total quality and flexibility, at minimum cost and delivery time.

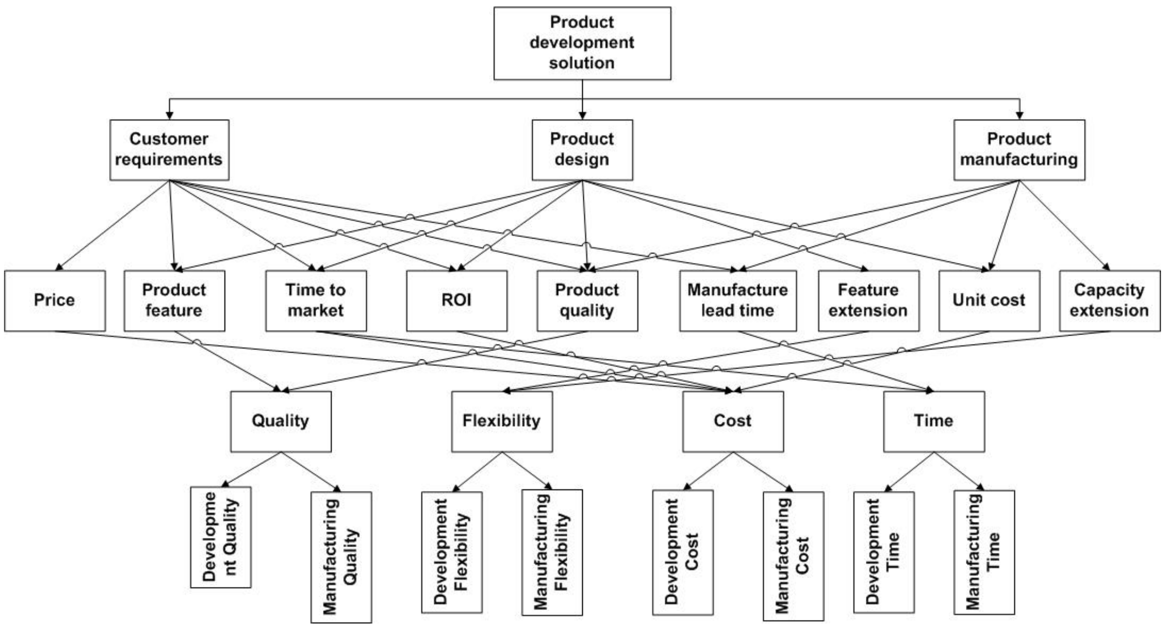

Figure 4. Abstract representation of Analysis of decision hierarchy criteria

5.3.1 Building a AHP model in Super Decisions

A Super Decisions model consists of clusters and elements (or nodes), rather than elements (or nodes) arranged in levels (see Figure 10.). When clusters are connected by a line it means nodes in them are connected. The cluster containing the alternatives of the decision. Nodes and Cluster are organized alphabetically in calculations.

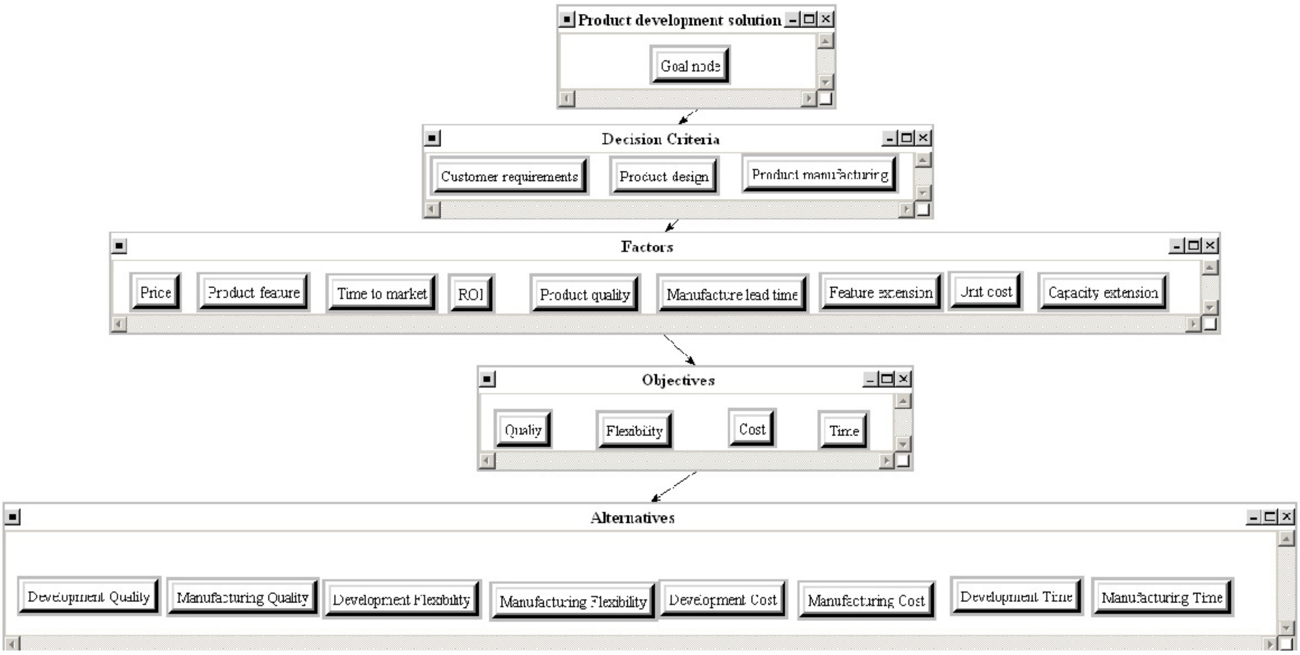

Figure 4. The AHP model

5.3.2 Assessments/pair wise comparisons

One of the major strengths of the AHP is the use of pair wise comparisons (see Figure 5.) to derive accurate ratio scale priorities, as opposed to using traditional approaches of "assigning weights" which can also be difficult to justify. Pair wise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared. Pair wise comparisons are carried out for all the parent/children sets of nodes. The nodes that are to be peewees compared are always all in the same cluster and are compared with respect to their parent element, the node from which they are connected. This results in "local priorities" (see Figure 6.) of the children nodes with respect to the parent.

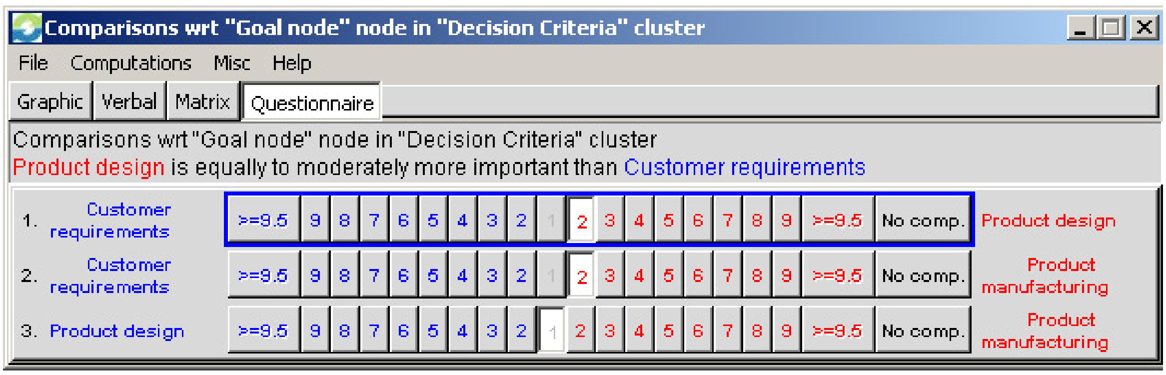

Figure 5. Questionnaire mode

Numerical judgements are made in matrix (see Figure 7.) using the nine-point scale that represents how many times one element is more important than another. The arrow at the left of the entry points to the dominant element.

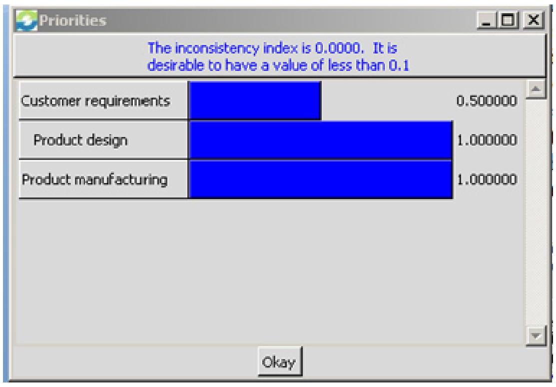

Figure 6. Priorities

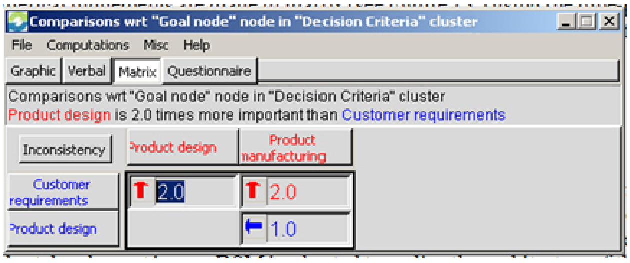

Figure 7. Numerical or matrix mode

Verbal judgements are used to compare factors using the word Equal, Moderate, Strong, very Strong, Extreme (see Figure 8.). Graphical judgements (see Figure 9.) are made by clicking and dragging the pie slice to change the relative size of the pie to the circle and the relative length of the two bars until it represents how many times more important one element is than the other.

5.3.3 Synthesis

The results for the alternatives are obtained with the Synthesis command (see Figure 10.). The Normal's column presents the results in the form of priorities. This is the usual way to report on results. The Ideals column is obtained from the Normal's column by dividing each of its entries by the largest value in the column.

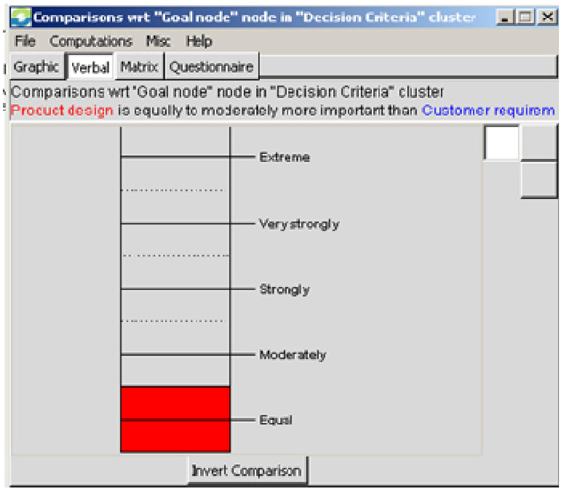

Figure 8. Verbal judgement mode

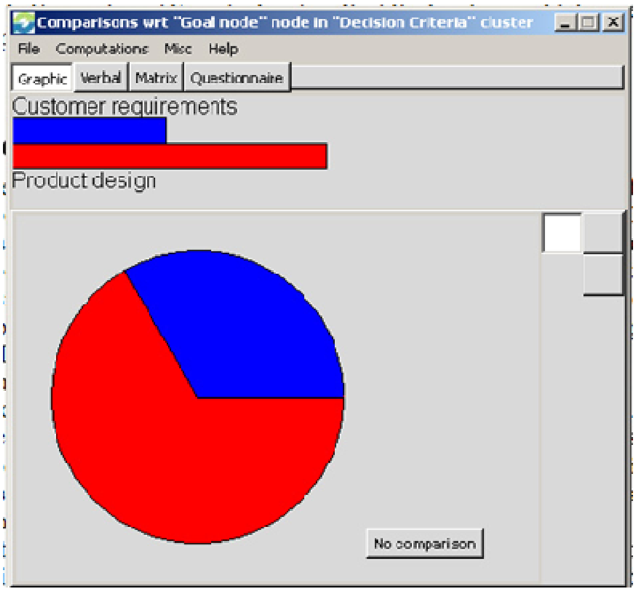

Figure 9. Graphical judgement mode

The Raw column is read directly from the Limit Super matrix. In a hierarchical model such as this one the raw column and the Normal's column are the same.

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: rad2.mod: formulaic

Name	Graphic	Ideals	Normals	Raw
Development Cost		1.000000	0.190729	0.047682
Development Flexibility		0.257557	0.049124	0.012281
Development Quality		0.943382	0.179930	0.044983
Development Time		0.560780	0.106957	0.026739
Manufacturing Cost		1.000000	0.190729	0.047682
Manufacturing Flexibility		0.257557	0.049124	0.012281
Manufacturing Quality		0.943382	0.179930	0.044983
Manufacturing Time		0.280390	0.053478	0.013370

Figure 10. Synthesis results

5.3.4 Sensitivity

If we want to see a meaningful graph it is necessary to set the independent variable. There is one line for each alternative in sensitivity windows (see Figure 11.). The priority of Product Design is plotted on the x axis and the priorities of the Alternatives are plotted on the y axis. Here we use criteria shown in Figure 18. But we can also explore sensitivity for the other criteria (changing parameters in Parameter Selection dialogue).

According to the information getting from analysis of decision hierarchy criteria in software tool "Super Decisions", we can do an evaluation of the product family and product platform development.

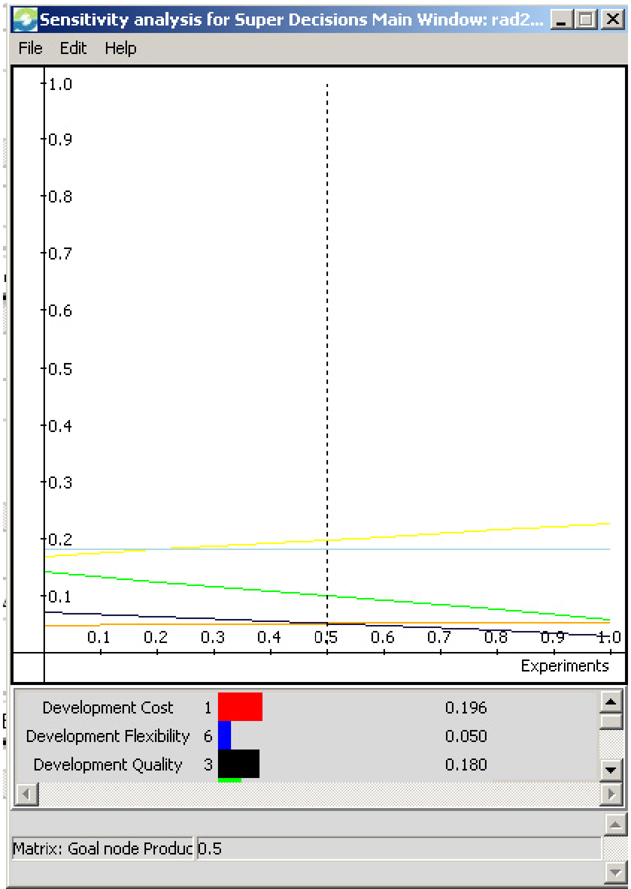

Figure 11. Sensitivity analysis

7. Conclusion and further research

The research objective in this paper was developing a new framework for achieving optimal platform products. Here were combining and integrating two methods: MFD method and multi-criteria decision making (AHP method). Advantage of MFD method is in the simplicity of use in project and the possibility of application throughout the life of a product. In evaluation is used AHP method which is standard technique for dealing with complex systems. The proposed framework could help to planning; generate design alternatives, evaluation and selection. Here is used "Super Decisions" software as a very powerful tool to help evaluate generated results into produce positive successful business projects. To demonstrate our framework, here is presented example of developing product platform of cooling generator with air-cooled condenser with axial fan and for outdoor position of installation. Framework also includes author's few years experience dealing with cooling generators in HVAC systems. The evaluation of the generated results will help us to produce positive successful business projects, in creating a quick method that will help in future decision makers to implement the evaluation of planning product families. We can say that this paper is focus also on practical issues and quickly implementation.

Future research could be continued to realize information system, for proposed framework, that should be investigated and implemented. This type of system could help decision makers to perform very early evaluation and planning product development projects. Also, framework is suitable for modular platform product development. In future we must seek to extend it to all types of product development. Also it will be very interesting to investigate AHP method in combination with some other tool, like fuzzy logic, which was proven as a very effective in help to get a good decision in case when we are working with multi criteria decision making.

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