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Supporting decision making and requirements evaluation with knowledge search and problem solving

Davide Russo*, Stefano Duci

University of Bergamo, Via Marconi 5, 24044 Dalmine, Bg, Italy

* Corresponding author. Tel.:+39 0352052353; fax: +39 035 2052077. *E-mail address: davide.russo@unibg.it*

Abstract

In the last years, several methodologies have been developed to organize and rank product requirements in order to plan a reliable innovation strategy. The main difficulties of these methodologies are the transformation of customers' needs in technical requirements, the subjectivity of the evaluation and the strong relation between requirements and the adopted technological solutions. The most structured methodologies use QFD (quality function development); sometimes in combination with other design theories. An easier and faster way is based on the evaluation of each product requirement by importance and satisfaction values.

In this article, a methodology called "KOMpetitive Intelligence" is proposed to make the evaluation of importance and satisfaction a more robust and consistent process. First, knowledge of experts is integrated with knowledge extracted from patents, market analysis, scientific literature and commercial literature. Second, the generation of new alternative solutions, coming from problem solving activities, are integrated in the evaluation process. Third, decision making and the definition of an innovation strategy are supported with a concise diagram that summarizes the gathered knowledge and facilitates the assessment of each requirement.

After several academic case studies, this methodology has been applied in a big multinational firm for two different products and is now on-going for the development of a third product.

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Keywords: Requirements, innovation potential, QFD, decision making, knowledge search.

1. Introduction

The launch of a new product usually involve conspicuous investments and risks. Best practice companies have implemented structured processes to effectively manage the development of a new product and increase the probability of success. The stage-gate process was introduced for this purpose [1] and some big firms implemented it for their product development activities [2,3].

Although many customized gate-models are practically applied in companies, the basic idea is composed of five gates [1]: initial screen, second screen, decision on business case, post-development review, pre-commercialization business analysis.

This paper presents a method that is specially adapted for the first stage of the stage-gate process, i.e. between the first and the second gates. Of course, this stage can be supported with a various set of methodologies, which can be found in literature [4].

QFD is the acronym of Quality Function Deployment [5], an approach to define customer needs or requirements, with a structured procedure to translate them into technical parameters and plans to produce products that essentially meet those needs.

Benchmarking is one of the first form of structured product development [6]; products are compared with industry bests from other companies and improvements are planned to cover possible gaps or to overcome competitor's performances.

An integration between QFD and Benchmarking was experimented by Kumar [7], but also many other integration involving QFD with other methodologies are recorded in literature [8,9].

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1.1. Defining requirements and new functions

QFD and other similar approaches start from the definition of a list of requirements (or desired and undesired features) that are usually related to the consumer's perception of "how the product should be". This task is usually performed with the help of a voice of customer [10] and through structured interviews with sales department personnel and factory representatives [11]. However, with a voice of customer, clients' ideas are often vague and ambiguous and they provide suggestions that are strongly related with what already exists. Furthermore, clients are not aware of new emerging technologies.

In order to obtain new functions, some methodologies involve the extraction of functions from patents [12], or from other online sources [13], such as forum or social networks.

1.2. Evaluating requirements

When a big firm must invest in the development of a new product, the allocation of resources should be concentrated on the most important requirements. In a problem oriented view, the identification of the main requirements can be associated with the formulation of the right problems to be solved. If the evaluation has been done correctly, the problems will involve the requirements with the maximum priority and customers will perceive the effect of innovation. As well as different problem formulations [14] can lead to different solutions, a different selection of requirements will lead to different problems and therefore to different solutions.

In order to identify the most important requirement, a series of methods that are called Importance-Performance Analysis (IPA) have been developed [11,15]. The ranking of requirements is done with two parameters: importance and performance. In one of the first experimentation of this method a questionnaire was sent to many people asking "how important a feature is?" and "how well the dealer perform?" [11]. The result was a series of opinions that could be visually represented in an Importance-Performance Cartesian graph. After some years, a similar approach was introduced with different terminology, "performance" is now called "satisfaction" [16]. Furthermore, a third parameter was added and was called "opportunity". This parameter combined importance and satisfaction to create an overall quantitative evaluation of each requirement. Other way of calculating "opportunity" have been presented. In the TRIZ world, Livotov 2008 suggested a new formula to calculate the "opportunity" value (or innovation potential) which was theoretically based on the concept of ideality extracted from TRIZ.

Despite the differences on the mathematical formula that lead to the ranking of requirements, the idea of IPA analyses is to concentrate innovation efforts on requirements which have high importance and low satisfaction. In fact, customers will perceive improvements just if their satisfaction is not already maximum, and this perception will be more determinant if the requirement is important for them.

1.3. Present limitations and proposal

Although the assessment of requirements has been recognized as a valuable process, its implementation is not easy and without complications.

During the evaluation of requirements, different people will have different opinions. These opinions are influenced by many factors involving personal background and knowledge. These differences can be found in both customers and experts, also among departments of the same firm. For instance, when creating a new product and making interviews, knowledge of previous experience may influence the evaluation; production managers may be more focused on requirements that simplify the manufacturing problems, sale personnel will request lower costs, engineers would ask for better technical performances and so on. Furthermore, requirements are subjected to language ambiguities, which are especially evident in abstract requirements such as "pleasing to see" or "that give the perception of a green product".

In this paper, an overall methodology is presented to make the evaluation and ranking of requirements a more robust process.

Interviews, patent information, marketing information and problem solving are not just retrieved, but presented during interviews to influence the evaluation of requirements. Specifically, infographics and maps are used to summarize information and give a comprehensive overview at glance.

The methodology has been applied in a big firm for the development of new products that are on the market from longtime.

2. Proposal

The proposed methodology consists of two phases: (1) information gathering and (2) requirements evaluation.

2.1. Information gathering.

The goal of this phase is to collect quantitative data that will be used to influence the second phase of requirement evaluation. The outputs are a report and an infographic map for each requirement. The first one is meant to provide a similar knowledge to everyone that involved the interviews; the second one to provide an overview of the present scenario and possible future scenarios at glance.

The standard procedure starts from a first audit with the "project manager", i.e. the "owner" of the project. During this meeting, the main function and the name of the product are identified, as well as the name of the persons that can be useful to collaborate in the definition of the list of requirements.

Knowing the name and function of the product, a fast screening of patent literature is used to identify competitors, patent density, and common problems of the product. The patent search can be integrated also with the reading of a commercial catalogues of the product.

A series of interviews are scheduled with at least a member for each department: experts from the marketing area, experts from sale area, experts of the technical area, experts of the manufacturing process and experts of quality. It is especially important to interview people that collect complaints of the customers. Interviews are performed to extract information on "how the product is" and "how the product should be". The concept of ideal final result is explained to each person to imagine the new product without any constrain.

Collected data are structured in a list of requirement that is proposed to the "project manager" for confirmation. The provided list of requirement has a nested structure, with more general requirements that form groups containing more specific requirements. For instance, "compactness" can be decomposed in sub-requirements such as "height, width, depth, footprint and volume". Note that sub-requirements are not necessarily technical parameters. This grouping operation is very important for not everyone is expert enough to provide detailed evaluations on all the specific aspects of the product, but they will usually be capable of assessing the importance of the more general requirement.

Along with the definition of requirements, the identification of main competitors are part of this phase. Known competitors provided by the company are eventually added to the new ones coming from the patent searches.

Information gathering is performed for each requirement. This information contain both state of the art and new potential technologies. The state of the art is built on four sources of knowledge: patents, scientific literature, product catalogues and the web. Where web searches are performed in competitors' websites and available web-search engines. These knowledge searches aim at positioning the product in comparison with the best solutions at the state of the art.

Note that state of the art searches are performed by looking for occurrences of the concepts "product category" and "requirement". For instance, if the analyzed product is a engine and the requirement is "compactness", the searches will include all possible solutions that improve or reduce the engine compactness.

Once a pool of document for a specific requirement is defined, the following information are extracted:

- Patent density: the number of patents applications during the years.
- Cooperation: the name of the companies that appear as co-applicants in patents.
- Regulation aspects and market structure: this is an interpretation of data about economic aspects.
- Technological alternatives: this is a classification of solutions available on literature. Differences are made if the technology is coming from scientific literature, patent literature or other sources. Furthermore, the presence of the technology on the market is also checked.
- Technological trends: as part of the previous point. Technological alternatives are represented in a timeline to identify technological trends of the past years.
- Performances: performances of commercial products of competitors are extracted.
- Investments: based on data availability, the investments of the company during the years, associated with a specific requirement are included.

Once the state of the art search is performed, a problem solving activity is necessary to understand "what may came next". In fact, decisions cannot be completed without a proper knowledge of possible future scenarios. The problem solving activity allows to include the following information for the evaluation:

- Technological new alternatives: this is a classification of new solutions not already explored in literature.
- Future technological trends: new and state of the art technological alternatives are analyzed from an evolutionary perspective, with the help of TRIZ laws of system evolution. The results are one or more descriptions of possible future scenarios.
- Ideality: using the concept of ideality, the IFR (ideal final result) for the considered requirement is generated.

At the end, each requirement will be accompanied with a big amount of information, which can be difficult to manage during interviews. An infographic overview on each requirement is built to provide ready to use information during the evaluation. The overview is printed in maximum two A4 pages and its use will be clarified in the next section.

2.2. Requirements evaluation.

The goal of this phase is to weight all requirements in terms of importance and satisfaction, eventually providing a ranking based on the market potential of each requirement. The output of this phase is an importance-satisfaction graph containing the weighted average values of experts opinions.

Jacoby [18] argues that importance is reflected in goal-oriented search attributes that consumers actively look for in the target product and consider when making a purchase decision. In a more simple and practical way, we define the degree of importance as a quantification of the influence of the considered requirement on the sales volume. In a scale from 0% to 100%, 100% means very strong influence while 0% means no influence at all.

Satisfaction is a measure of how products and services supplied by a company meet or surpass customer expectation [19]. In a scale from 0% to 100%, 0% is the absence of the feature or great dissatisfaction, 100% is maximum satisfaction. The aforementioned definitions are given to experts before the interviews for the evaluation, which are described in the following paragraph.

The "project manager" will schedule a series of meeting with the experts. Also in this phase, as in the definition of requirement, an interview with a person of each department is necessary. If possible, more than one experts from the marketing area are required for they are the one with more knowledge of the customers. Some days before the interviews, the report and the infographics are sent to the experts to make them acquire knowledge.

Interviews can be performed with one or two person at a time. The infographic overview of each requirement is shown and used for discussion during the interviews.

First, the evaluation of importance is performed. The evaluation of importance is usually more reliable through a comparison approach than asking for absolute values [20]. For this reason, the interviews are performed with the following rules, placing post-it on a graduated scale:

- First, the leader explains the most interesting result of the analysis with the help of the summary infographic.

- For the first requirement: he asks to select a value from 0% to 100%.
- For the requirements that follow the first one: he asks to select a value from 0% to 100%. Then we ask if the requirements with the closest rate is really more important or less important. If the opinion change, we repeat this step.

The evaluation of satisfaction is performed simply by asking to impersonate the customer and imagine its degree of satisfaction for the product, comprised from 0 to 100.

After the interviews, data are elaborated to provide the final weighted values of importance and satisfaction. A simple weighted average can be used, as well as an average based on ranking considerations [20]. Regardless to the specific formula that can be used, more weight is usually given to raters that are considered more close to the customer. The final result of the evaluation is an Importance-Satisfaction graph as shown in figure 2. Improvements on requirements on the bottom-right corner of the graph will likely to be perceived by the customer. Although the ranking of requirements can be presented with the aforementioned graph, the list of requirements can be sorted with one of the formulas to calculate the market potential (or opportunity index) [12,16]. Specifically, in our approach, we used a normalized version of the opportunity index (inspired from [16]): MP=(100+I+(I-S))/10. Where, MP is the market potential index, I is importance and S is satisfaction of a certain requirement. In this way, the market potential is a positive number between 0 to 30. The formula is studied to give a higher rank to a requirement that is considered very important with very low satisfaction, lower rank to a requirement that is considered not important with high satisfaction.

2.3. The innovation strategy

The graph of figure 2 represents a fast and easily understandable overview on the current client's satisfaction and importance values of the product. The next step is called "definition of the innovation strategy" and is created to define the identikit of the future product. The new product will be depicted using the same importance-satisfaction graph, where importance or satisfaction may change:

- Importance changes: habits of customers can change during time, and feature with little importance can become of high importance. In some rare cases, such as when the company has the monopoly on a certain product, importance can be manipulated through sensitization or desensitization campaigns.
- Satisfaction changes: the satisfaction value can be changed by changing the performances associated with a certain requirement, or the perception of that requirement.

The definition of the innovation strategy is represented in the same importance-satisfaction graph as arrows. The length of these arrows provide a quantitative idea on the changes. In this phase, problem solving information (which are present on the infographic sheet) are critical to suggest improvements that are feasible, at least from a conceptual point of view.

3. Case study

In this case study, we consider the development of a new electrical device for a multinational company. Data are partially hidden and suitably modified to hide any confidential information.

3.1. Information gathering

In accordance with the first step of the methodology, the list of requirements has been defined through a series of interviews with at least one person for each department of the firm. The collected information was reorganized in a series of requirements. The nested structure of requirements can be seen in table 1. Patents about the product and web searches help in finding competitors.

Table 1. Nested requirements list.

Energy Consumption	Phase 1 power consumption
	Phase 2 power consumption
Peak power	Peak power consumption
…	…

For each requirement, a comprehensive search and a problem solving activity are performed. Reports of this activities was sent to the "project manager" for approval. After this, reports were sent to the persons who were going to participate in the following interviews.

Here follows an example of information that were provided for the requirement "Presence pressure monitoring". The following information were used for the evaluation:

- Patent distribution during the years: the patent activity revealed a strong increment on the last years and an increasing diversification of the agents/companies.
- Performance comparison: we compared performances about the peak power and continuous power consumption.
- IFR: the minimum amount of energy necessary to perform the function has been identified with ideality, along with a conceptual solution to reach it.
- Problem solving: a classification of all the solutions derived from the problem solving phase is presented as a map. This map is developed by TRIZ experts with the help of a functional based search [21].
- …

Figure 4 shows the summary of this information in the overall infographic representation.

3.2. Requirements evaluation.

Interviews were performed with several experts from marketing, two experts from the technical area and one manager from sales area. Given the time limits, other people were interrogated through a questionnaire sent through e-mail. The interviews were performed following the rules of paragraph 3.2, with outputs such as the one of figure 1. As it can be seen, evaluations are divided into areas for the markets are different for each country (zone). An average value for importance and satisfaction has been extracted.

	Asia			Europe		
	Overall Importance %	Overall Satisfaction %	Market Potential	Overall Importance %	Overall Satisfaction %	Market Potential
Energy Consumption	15	60	7	50	40	16
Compactness	10	75	4,5	25	20	13
Requirement 3	10	50	7	10	50	7

Fig. 1. Output of interviews divided into different groups of customers.

In the average calculus, e-mail's questionnaires were considered with less weight than proper interviews and the example for the final outcome of one zone is shown in figure 2. Results from phase 1 are used by experts to conduct the evaluation process dealing with the market potential of each requirement.

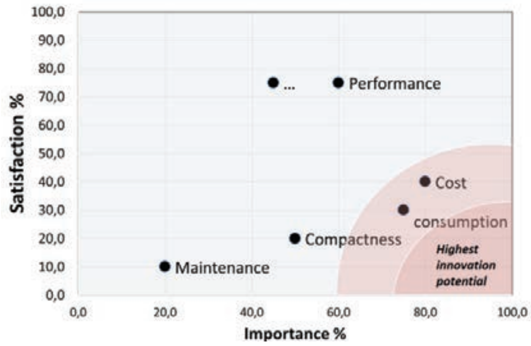

Fig. 2. Graphical Importance-Satisfaction ranking.

3.3. Innovation strategy

The example in figure 3 shows the innovation strategy for a new product. Arrows indicate the changes that will characterize the new product. The general objective is to have a greater satisfaction for each requirement, preferably for the with the highest innovation potential (see figure 2). In the example of figure 3, a strong cost reduction is used to strongly increase the satisfaction of the product. To do that, it is also acceptable to slightly reduce satisfaction for other requirements with lower market potential and lower importance. One or more innovation strategies have been proposed to the "project manager" and the other persons that were responsible for investments.

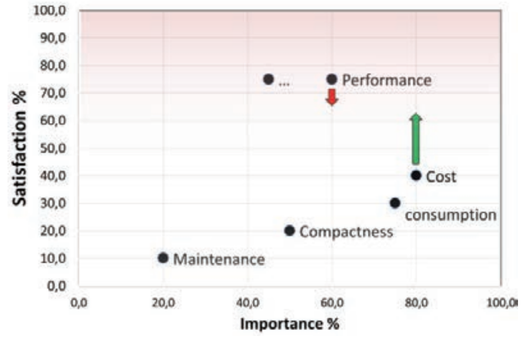

Fig. 3. An example of innovation strategy.

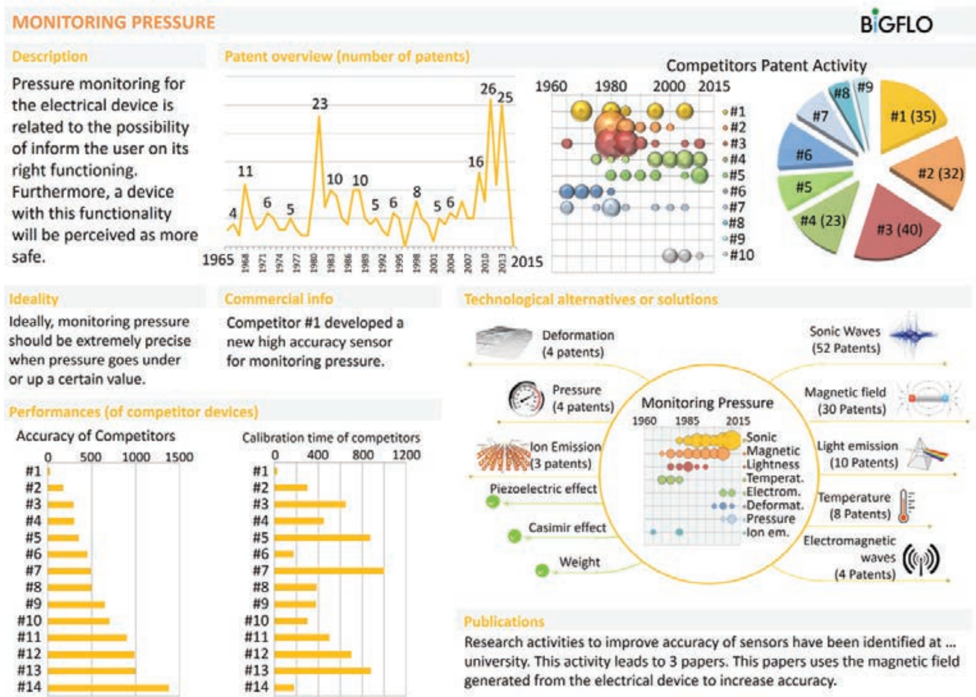

Fig. 4. Example of infographic for the requirement monitoring pressure.

Although this phase can be organized with interviews and further evaluation, in this case study, the final decision was discussed in two meetings with R&D managers from different departments.

4. Conclusions

This paper presents a systematic procedure, mainly based on TRIZ, that facilitates the introduction of TRIZ in a stage-gate organization of multinational firms. Specifically, it has been conceived for the early phases of product development.

Existing methodologies rank requirements on the base of importance and satisfaction values. Both the identification and weighting of requirements are usually performed without a systematic methodology, relying on the experts' knowledge and somehow on the unquestionable judgment of leaders. The main risks of these approaches are the strong subjectivity of the evaluation and the strong dependence of the evaluation with experts' knowledge. The presented methodology combines knowledge search and problem solving. It was developed through several years of experimentation and specifically built to overcome the aforementioned problems.

First, knowledge of experts is integrated with knowledge extracted from patents, market analysis, scientific literature and commercial literature. Second, the generation of new alternative technologies is supported with a systematic theory of problem solving and knowledge transfer. Third, decision making and the definition of an innovation strategy are supported with a concise diagram that summarizes the gathered knowledge and facilitates the assessment of each requirement. Gathered knowledge and problem solving foster the ability of experts to identify and rank requirements. In some cases, completely new technologies or solutions are identified to be suitable with the considered application.

The graphical summary allows experts and leaders to have a comprehensive and fast overview on the situation, increasing awareness and consistency of decision making during the interviews. Some typical situations has been recorded on how the provided information changed the judgment of a requirement. Although not specifically demonstrated, subjectivity is likely to be reduced thanks to shared knowledge and new problem solving. A general problem solving activity allows the construction of different scenarios that are useful for the evaluation, while the laws of technical evolution allows a better understanding of future drivers. The selection of personnel for the interviews is structured to facilitate communication between different departments of the firm.

A first limitation of this analysis is similar to many similar information retrieval processes. It implies the availability of the needed information. Mentioning the direct experience coming from the aforementioned case study, selling volumes would have been very useful, as well as other marketing searches that were not included for confidential problems. Among them, a structured voice of customers and interviews with customers were missing. In this way, information is somewhat filtered through the company's personnel.

Another limit of the evaluation is to consider requirements as independent from each other to facilitate the judgment of experts. This limitation is partially overcome by the visualization of requirements in the importance-satisfaction graph, that allows to easily identify trade-off and indirectly consider influences among requirements. However, there is not a specific way to effectively manage the complexity of requirement's correlations.

After several academic case studies, the proposed methodology, under the name of “KOMpetitive Intelligence” has been applied in a big multinational firm for two different products, with encouraging results. Another project, which involves the methodology, is on-going for the development of a third new product. As side effect, these activities encouraged the spread of TRIZ inside the company.

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