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AN INTEGRATED APPROACH FOR THE QUALITY MEASURE OF INDUSTRIAL PRODUCTS

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1. Introduction

The primary importance of design activities in assessing and improving the quality level of products has been detected by many Authors, who have pointed out the fundamental relationship between Quality, Cost and Time. With the aim of following this approach and trying to overcome the difficulties concerning the use of the traditional design tools at the same time, the research work carried out was focused on the of development of a design procedure which can be applied in the initial stages of the design process in order to support the decision making activities, optimizing the use of traditional methodologies.

Bearing this in mind, also the possibility to provide practical tools for the evaluation of Quality was considered throughout the development of two different software aimed respectively at assessing internal product's characteristics (i.e. product's technical properties), and at using the Quality Function Deployment method in synergy with other support tools (such as Wassermann technique, AHP, and so on) for the assessment of external product's requisites, e.g. Customers' needs, Legislation requirements, etc.

More in detail, the paper summarizes and discusses the results of a two year research work carried out in collaboration with the Italian Institute for Safety for Prevention and Safety (ISPESL) and aimed at the development of design tools for the measurement of the quality level of products in design stages.

In the first section, a brief discussion about the definition of Quality and its conception from different perspectives is presented: in fact, depending on who is assessing the quality level of a product (designers, producers, customers, sellers, etc.) the aspects underlined are sometimes in conflict with one another, so that defining the exact meaning of "Product Quality" as well as finding a correct set of evaluation criteria is surely a difficult task for engineers.

In the second part of the paper, the research approach is presented: in particular, a similar approach to the ones used in the field of Service Engineering and Quality Management was considered, developing a measurement ratio based on the evaluation of indicators ("sensors") concerning most significant properties of industrial products (e.g. Safety, Reliability, Aesthetics, etc.). This led to the development of an original software tool, called "Quality Measure Tool" (QMT), for the application of such criteria in an easy and rapid way. Moreover, with the aim of taking into account Customer Needs and other external requisites that a product should satisfy, the design tools for traditional "Design for Quality" (DfQ) were analyzed: among them, the Quality Function Deployment was further studied and implemented in a software tool called "Integrated QFD" method.The final aim of this part of the study consisted in the definition of a proper design procedure for the evaluation and the improvement of products Quality level. In the last part of the paper, the application of such an approach is shown by means of an industrial case study.

2. Background and Motivations

2.1 The definition of Quality for industrial products

In last decades, different approaches have been proposed addressing the principles of Quality to a specific target based on a particular context. Following the historical evolution of Quality in the industrial field, starting from the approach of Total Quality in the sixties, up to the recent models proposed by the latest version of ISO 9000 standards, the Six Sigma, the "awards system", etc., the continuous changes that have characterized its implementation in companies are clear and significant.

Numerous definitions of Quality have been provided hitherto, as well as a variety of methodologies aimed at its assessment and improvement: though quality experts have provided their own interpretation of Quality (e.g. Juran, as "Fitness to use"; Taguchi, as "Loss a product imparts to the society after being shipped"; Crosby, as "Conformance to requirements"; etc.), others have tried to classify the different meanings of Quality distinguishing different categories depending on the point of view from which it is assessed, i.e. users', manufacturers', citizen's perspectives, and so on.

Furthermore, we also have to consider that Quality is not only an engineers' matter, but it also largely involves other departments of the company (marketing, management, etc.): needless to say, we can find various approaches and definitions from these points of view. On the basis of these considerations, while on the one hand the various interpretations of the Concept of Quality can appear different one from the other; on the other hand it can be argued that the same concepts ("Fitness to use", Conformance to requirements", "Customer satisfaction", etc.) have provided different results when applied, depending on the historical and technological context.

Thus, analyzing the needs of the modern society it is clear that requisites that an industrial product should be in compliance with have become more numerous and stricter than in the past, involving also social aspects, i.e. the impact that the product has on the society in general, considering for example its performances from the safety and the environmental point of view. Following such an approach we can distinguish at least four different categories of requisites that the product has to satisfy:

- The requests of the direct users.
- The needs of manufacturers and other companies involved in the product development (e.g. suppliers, dealers, etc.).
- The requisites concerning the application of laws and regulations affecting the specific product (e.g. the Machine Directive, the RoHS Directive, etc.).
- The requisites aimed at reducing and/or optimizing the burdens of the product on the society.

On the basis of these considerations, the differences among the above mentioned definitions appear less significant and it can be argued that they express the same concept considering different points of view: e.g. the well known Taguchi's definition cited before appears very close to the latest studies concerning the societal aspects of Quality [Kano, 2005].

2.2 The assessment of Quality

One of the most significant key factors in developing high Quality product is represented by the ability of engineers to correctly evaluate its performances before putting it in the market, in other words, to understand in advance how the product will fit the needs and the requests of all stakeholders [Pugh, 1990].

On the one hand, it has to be noticed that, the necessity to put on the market competitive products reducing as much as possible the "time to market" has brought most of the companies to minimize research activities for the development of new and innovative products.

On the other hand, the need to offer a diversified production able to satisfy different customer needs nowadays has nevertheless become ever more fundamental. In addition to the ever greater complexity of modern products, engineers have to deal with the pursuance of new regulations and laws the product and the company itself have to be in compliance with (e.g. the regulations in the field of Safety and/or the recent European Directive in the environmental field). This represents a significant problem for companies both because it requires radical modifications of products' design and manufacturing processes, and because it needs additional costs which companies have to bear.

For these reasons, the achievement of the optimum agreement between technical aspects and characteristics of products (including costs!), and the satisfaction of the requisites of other stakeholders has become very hard for companies: making the correct decisions in the early stages of the product development plays an important role to enhance the products' performances, simultaneously improving companies' bottom lines [Fargnoli et al., 2004]. In particular, the development of well founded design concepts can be substantial to obtain products that fulfil the design requirements in a more efficient way: in fact, the most significant feature of such an address, as well as the most difficult to be correctly satisfied, is certainly represented by the selection stage, i.e. the definition of appropriate criteria on the basis of which to perform the selection among the best design alternatives in the most objective way [Eder, 1998].
On the other hand, it has also to be underlined that the more necessary the choice is at the initial stage of the design process, the more difficult this task is, because of the low level of information compared with the great number of requisites that designers have to take into account.
Considering the specific literature concerning the Product Development (PD), numerous different approaches can certainly be found, focusing in particular on the evaluation of the characteristics of already existing products and improving their weak aspects: actually, such a strategy often corresponds to the real need of most of companies, in particular medium and small sized ones, that often have the necessity to upgrade their products and cannot risk investing time and resources in a completely new solution [Andreasen, 1992; Suh, 2001].
The research work, started in 2003 [Fargnoli et al., 2004], was aimed at the solution of such remarkable problems during the product development. More in detail, the basis of the research work was represented by the latest development of the management issues in the field of the:

- Quality Management Systems (QMS): the recent revision of the ISO 9000 standards and, the more specific approaches for particular sectors, such as Six Sigma.
- Service Quality, i.e. the comparison of customer expectations with performance perceptions by means of the application of some measure tool, such as "Servqual" [Lee et al., 2000], or "Qualitometro" [Franceschini et al., 1998], and so on.

Both these approaches, in fact, provide criteria for an objective evaluation of the Quality level, as well as for the measure of the Customer Satisfaction. Following these indications, the goal of the study consisted in the working out of a "Quality Measurement Procedure" to be used in the initial stages of the product's development.

3. The Quality Measurement Procedure

The development of the Design Procedure for the measure of the quality level of products during their development was articulated considering the evaluation and optimization of both the external and internal drivers:

1. Internal Drivers: the requisites of manufacturers and other stakeholders involved with the product development, including in this category the intrinsic characteristics of the product.
2. External Drivers: the needs and the expectations of users and in general of the society, as well as the requisites of the various laws and regulations.

Needless to say, the aspects related to these two categories are not independent one from the other, but they are more or less interwoven mainly depending on the nature of the product.

3.1 Internal Drivers

In order to take into account all attributes that characterize the product from the engineers point of view, a series of properties have to be analyzed, in accordance with the "Methodical Design" theory: the assessment of such properties allows the designers to develop a measure of the product's Quality level, and at the same time shows which characteristics have to be modified in order to obtain an improvement of the whole product's quality. On the basis of such an approach, the following properties can be distinguished:

1. Aesthetics
2. Assembly
3. Attitude to be manufactured

4. Attitude to be stored
5. Cost
6. Disassembly
7. Environmental Impact
8. Ergonomics
9. Functionality
10. Maintainability
11. Packaging
12. Performances
13. Recycling
14. Reliability
15. Safety
16. Transportability
17. Usability.

With the aim of defining correct criteria for each one of such properties in order to obtain a precise and objective evaluation of the product's quality, the approach followed was based on the "Qualitometro" [Franceschini et al., 1988], throughout the development of an opportune "Sensorial Pyramid" [Fargnoli et al., 2004].

The output of this study was the development of a series of checklists which takes into account all the above mentioned properties, providing at the same time both the general information concerning each characteristic considered, and the criteria for its evaluation by means of the definition of specific indicators.

The definition of an easy-to-use guideline able to indicate in practice to designers how to evaluate the performances of the product even in the initial stages of its development was carried out by means of the development of a software, called "Quality Measure Tool" (QMT), based on a series of evaluation checklists.

In Figure 1 an example of the QMT is shown: for each property a series of evaluation criteria were provided ("c.v." in the figure); the software is particularly suitable for the comparison among different design alternatives.

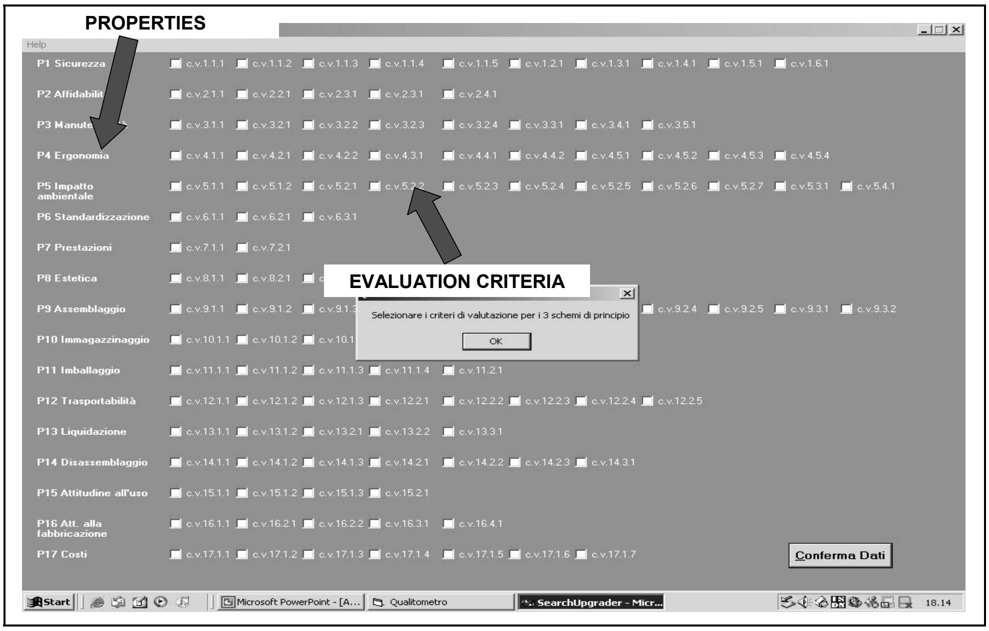

Figure 1. Example of the Quality Measure Tool

3.2 External Drivers

In order to consider the expectations and needs of the external stakeholder, the attention was focused on the use of the Quality Function Deployment (QFD) method, because of its efficiency in the interpretation of customer needs and translating them into engineering parameters [Akao, 1990].
More in detail, the use of such design tool together with several techniques for the optimization of its outputs was analyzed, and the following supporting tools were considered:

- The Kano Model.
- The “Affinity Diagram” [Raymond, 1997].
- The “Wasserman Normalization” [ReVelle, 1998].
- The Technique for the deployment of the Correlation Matrix (CMT) [ReVelle, 1998].
- The “Analytic Hierarchy Process” (AHP).

The output of this study allowed us to develop a complete procedure for the integrate application of the QFD and the above mentioned techniques: the results were implemented in a software, called “Integrated QFD” (in Figure 2 an example of this tool is shown). Beside such tools, others methods were considered, such as Benchmarking [ReVelle, 1998] and Axiomatic Design (AD) [Suh, 2001].

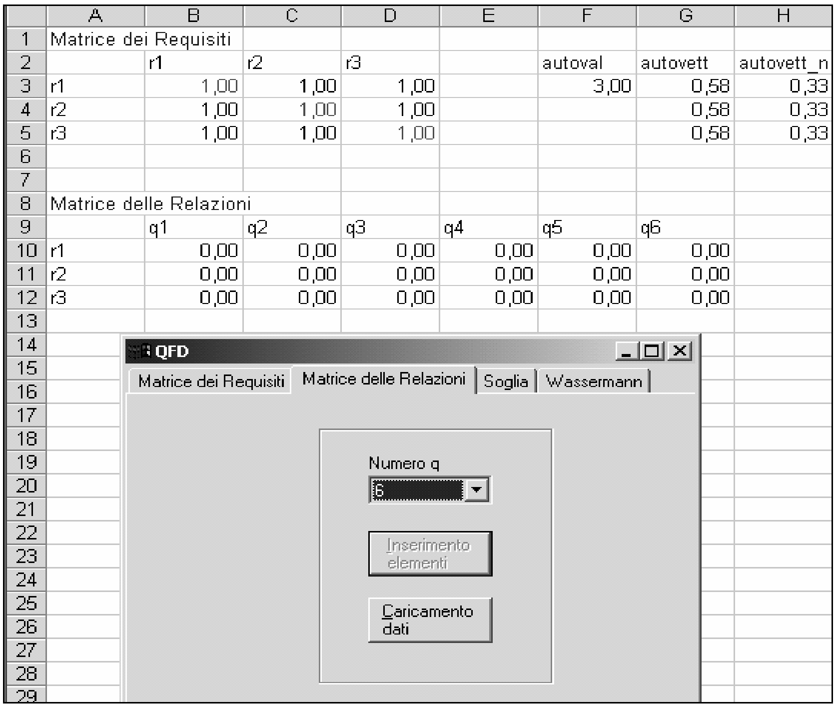

Figure 2. Example of the “Integrated QFD” software

3.3 The Design Procedure

In order to optimize the use of such tools a design procedure has been developed that is characterized by the application of the above mentioned methods and techniques aimed at clarifying which interventions/modifications can be carried out during the product’s design and development process.
As far as design strategy tools are concerned, in literature several models of the design process have been proposed hitherto and, needless to say, all of them are characterized by a similar identification of the main design activities. In particular, the model used in this research work is divided in four main phases: clarifying the problem (task analysis); conceptual design (function analysis and organ structure definition); embodiment design (preliminary and dimensional layout definition, production

characteristics' analysis); test (constructive layout verification and validation). In Figure 3 an excerpt of the procedure concerning the Conceptual Design phase is shown.

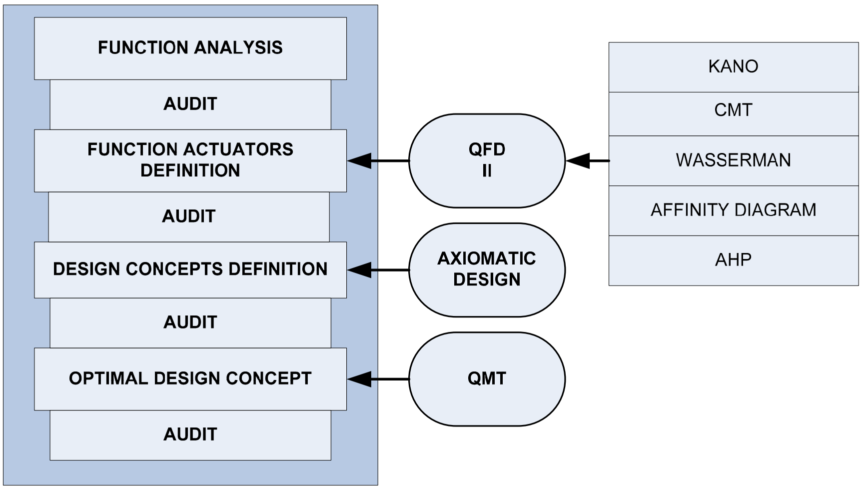

Figure 3. Second phase of the Design Procedure

4. Case Study

The validation of the research approach and the optimization of the two software developed were performed through their application to a case study, the redesign of a can used for tinned goods in collaboration with an Italian manufacturer (Figure 4). In particular, the study concerned the optimization of the product taking into account all stakeholders needs:

- the users of the product, i.e. the customers that purchase the can;
- the producer of the can, also in charge of filling the can with the food and distribute it;
- the specific regulations concerning both safety and hygiene;
- the impact of the product in terms of environmental burdens, i.e. the recycling possibilities.

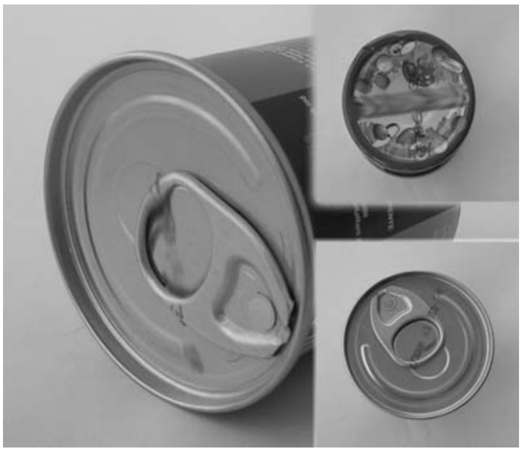

Figure 4. The can object of the redesign

In the first phase of the design process, technical characteristics and stakeholders requisites were analyzed throughout the application of the both the software developed: the main results are summarized in Table 1.

Table 1. Main results of the QFD application in the first phase of the design process

R.1 SAFE TO OPEN
R.2 HERMETIC CLOSURE
R.4 SAFE TO HANDLE
R. 7 SAFE FROM THE HYGIENE POINT OF VIEW
R.11 CLEAR INFORMATION ABOUT THE FOOD ON THE CAN'S BODY (DIMENSIONS)
R.13 CLEAR INFORMATION ABOUT THE FOOD ON THE CAN'S BODY (SILK-SKIN PROCESS)
R.14 EASY CONNECTION BETWEEN THE COVER AND THE BODY OF THE CAN
R.18 RESISTANT TO THE STERILIZATION PROCESSES (MATERIALS)
R.22 RESISTANT TO THE STERILIZATION PROCESSES (STRUCTURE)

In the second phase of the design process, in accordance with the procedure's scheme shown in Figure 3, the second House of Quality of the QFD was applied in order to define the main actuators of the system's functions. Moreover, with the aim of generating several design alternatives the Axiomatic Design method was used: the use of the Quality Measure Tool allowed us to determine the optimal design concept among them. In Figure 5 results of such an application are shown; in Figure 6 the general layout of the optimal design option is represented.

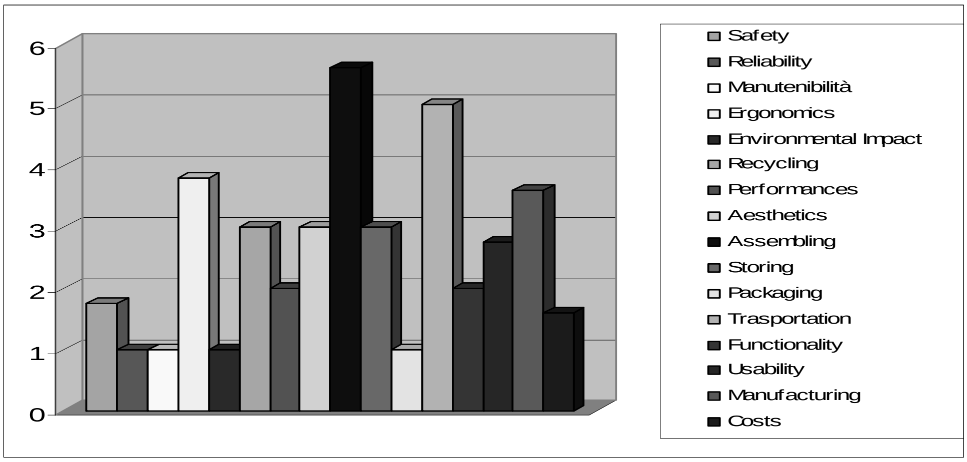

Figure 5. Measure of the Quality level of the optimal design concept using the QMT software

Thanks to the ease of use of both software, technicians could carry out a complete analysis of the existing product and compare it with the possible solutions developed. The checklists enclosed to the QMT resulted in being very helpful in considering all technical parameters of the product, providing simple criteria for the evaluation. The QFD software helped in taking into account external drivers in a clearer way, increasing in particular the specific weight of consumers' needs in decision making.

5. Conclusions

In this paper the results of a study concerning the development of an effective design procedure able to lead designers to carry out a list of optimal design choices as solutions of design conflicts and constraints caused both by the plurality and diversity of technical and technological requisites are presented. Results obtained were considered positive from the manufacturer: the company's technicians, who were not expert in the field of Design for Quality could easily apply both the two software developed and decided a further the implementation of the solution carried out from the present study, particularly for what concerns the can cover.

The design approach developed can certainly be applied to the design of any type of product, increasing its performances as well as improving its market competitiveness. Moreover, the assessment tools developed turned out to be very suitable for their integration within the design process, and easy to use even in the analysis of complex systems.

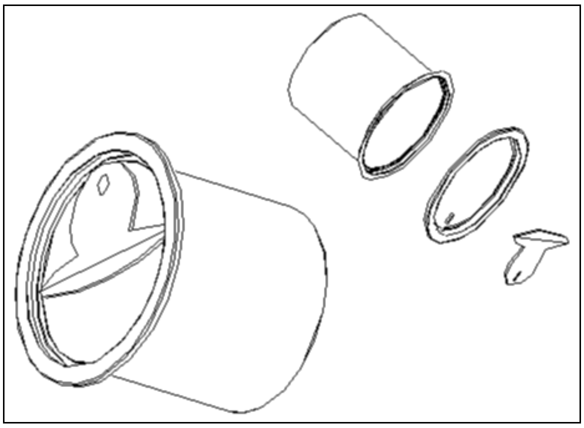

Figure 6. General layout of the redesigned product

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