Case study in product quality and environmental planning to achieve comfort within indoor working spaces*

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Abstract. *The present work presents a demonstrative application for defining the needed measures to implement quality and environmental planning provisions at product level within a furniture start-up company that seeks to transfer newly developed products into production. The conceptual models of D. A. Garvin and N. Kano are used as basis for this endeavor and the resulting proposals can constitute the basis for concrete approaches such as ISO 9001 systems, Lean Six Sigma, Kaizen events or other. For the product related environmental aspects, the Bill of materials generated by the CAD software CATIA is used as the starting point for analysis. A modality of structured deployment of measures is presented, a "red thread" that runs from identifying and understanding the customer requirements, to design and development, to production and delivery and, ultimately, returns to the customers in order to assess their overall satisfaction along the product lifecycle. The authors consider that such an approach has the advantage of being, at the same time, scientifically sounds, technically useful and practically implementable, offering a tool which is easy to use in a company that combines R&D with market orientation against the usual background and challenges of launching a new business.*

Key words: *quality planning, environmental planning, Garvin's 8 dimensions of quality, Kano model.*

1. Introduction

The current paper proposes a possible scenario for developing the adequate measures needed to perform product quality and environmental planning for a furniture start-up company focused on developing innovative furniture by incorporating RDI activities at the center of its business model, with the support of European Funding in the form of the project POSCCE 12.P01.001 13 C3, Research for developing and implementing into production innovative furniture, part of the 12.P01.001 Competitiveness Pole "Transylvanian furniture cluster". As the project is nearing completion, a product portfolio has been developed by the researchers and designers and the company is considering its options in turning these products into market successes with the help of the newly implemented production system. For this purpose, a special focus will be dedicated to ensuring the proper realization of quality

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at product level, both by means of correct planning and optimized control, while at the same time maintaining a minimal environmental footprint.

For the needs of the present endeavor, quality as a goal will be approached by means of approaches proposed in the 1980s by professors David A. Garvin in the US and Noriaki Kano in Japan. The choice of these approaches is based on the need to define in an exploratory manner the possible future customer niches and to design into the products all the possible measures to ensure their success from early on, no matter what concrete form they take during implementation: ISO 9001 Quality management system objectives, Lean Six Sigma DPMO targets, Kaizen events programs or other means. This is due to the high degree of competitiveness on this market [1], both in Romania and abroad, where, even an innovative product, can fail quickly and be rapidly replaced if it does not meet the cost and performance expectations in a short time span (furniture is leaning in the past decades more towards the commodity end of the product novelty scale and attempts to push it towards the innovation end are still required to be good and cheap from start). The product interactions with the environment are mainly treated in this paper by means of analyzing and understanding the impact that the chosen materials have on the sustainability of resources, the quality of affected environmental factors (i.e. air) and the challenges of recycling at the product's end of life.

2. Structuring customer requirements using the Kano model

The Kano model [2,3] groups the requirements of the customers into three categories: mandatory (they must be fulfilled for the customer to perceive satisfaction), performance (the more the better to entice satisfaction) and surprising (a few unconscious requirements whose fulfillment brings a considerable return on investment). In the case of the analyzed furniture start-up company, based on focus group studies and the company policies, the market for residential and business (office) work furniture, respectively, yields the following requirements (Table 1):

Table 1

Customer requirements analysis

Kano model category	Identified requirements Residential work environment	Identified requirements Business work environment
Mandatory	Durability Main function	Durability Easy maintenance Main function Cost effective
Performance	Comfort Easy to transport/Light Customization possibilities Precision of execution Distinction of materials Integration into trends Color/Texture/Aspect Delivery/Installation Cost effective	Re-configurability Professional aspect/image Precision of execution Distinction of materials Fireproofing Office equipment readiness Ergonomic working position Common spare parts / repairs Delivery/Installation/Recovery
Surprising	Design approach Multi-functionality Re-configurability	Multi-functionality Smart capabilities Recyclability

3. Structuring quality measures using Garvin's 8 dimensions

Prof. David A. Garvin proposed in his article from HBR in 1987 [4, 5], an approach to quality structured on 8 main dimensions that relate both to product and process levels: performance (main function), features (all other functionalities), reliability (constancy of functionality), conformance (adherence to expected norms), durability (time related behavior), serviceability (ability to be repaired), aesthetics (design preferences), perceived quality (satisfaction generated).

We shall use these direction to continue the presentation of how the identified customer requirements are used to generate product characteristics and an individualized process structures within the production system. A typical furniture type that can be included both in the residential and the business categories, namely a work desk, is used in the following to exemplify the results of thinking up the activities of the company through the dimensions mentioned above, using the proven advantages CAD/CAM/simulation software [6]. The main design themes are based on a survey of real customer requirements in terms of dimensions, functionality and aspect.

The *performance* of the product is visible in Figure 1 below, which shows the CAD model used for product design and indicates the main function of the product – to support work related activities. Based on the 3D model, all the necessary data for production can be derived: dimensions, tolerances, materials, fittings for assembly, accessories, etc. In this way, the room for error between the design and the production processes is minimized and time to customer is very short.

Figure 1. Example of a desk design (CATIA 3D model)

Also, some of the *features* of the product, which are design into it and then manufactured, can be seen in Figure 1: extended working area with two side at 90° angle, thick and stable working surface, mobile file and documents storage unit (roll box) with 3 separate drawers, open space on both sides (no front covers), stiffening elements connecting the wooden legs, one design and support metallic leg on the corner, sober finishing. Besides this, some hidden characteristics must also be mentioned: the wood particle boards must have the proper thickness and their edges

must be processed with ABS before assembly, the assembly pins, holes and glue need to be integrated and anti-slipping and anti-humidity legs need to be installed. Also, the document cabinet has its own mechanism and accessories that must be included: wheels, drawer guides, handles, etc. All the features are achieved through proper design and manufacturing according to CAD specifications (Figure 2).

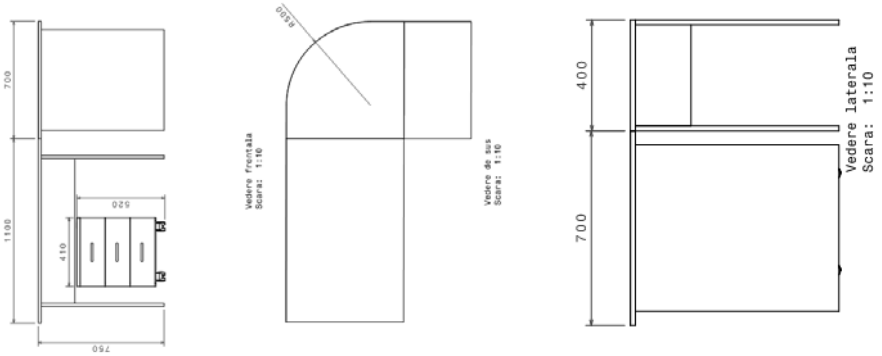

Figure 2. Product related features (overview drawings)

The *reliability* has been described in terms of FEA (finite element analysis) study that has tested through simulation the stress that the product must endure, using a uniformly distributed force of 2000N, 2 supports for each particleboard leg and 1 support for the metallic leg (Figure 3a). The results of the study indicate that the maximum possible deformations do not exceed the allowable limits of the material, thus the product is able to perform its function in a continued manner.

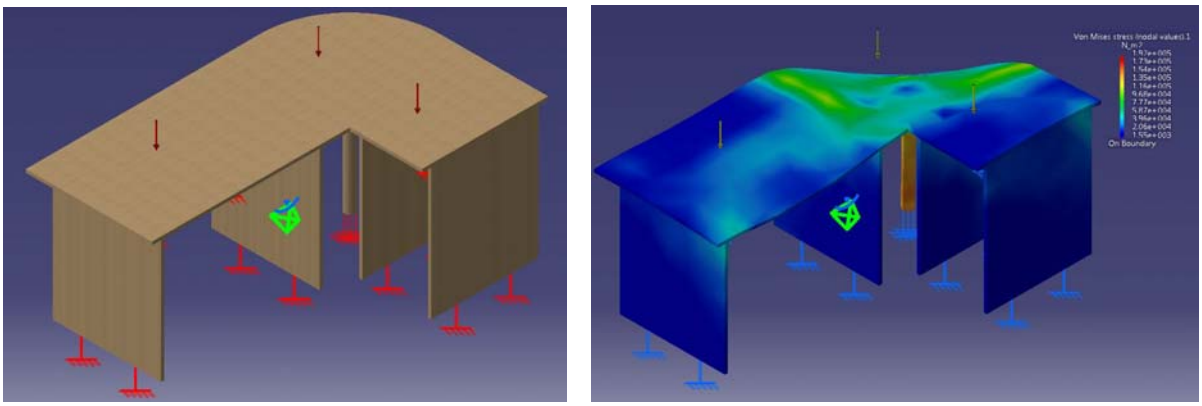

Figure 3. a) FEA setup; b) FEA results

In order to ensure *conformance* of the product with norms and regulations, the following standards will be observed during product design and manufacturing:

- STAS 147-88 – Wood furniture. Work tables and desks (Romanian standard)
- EN 527-1:2011 – Office furniture. Work tables and desks. Part 1: Dimensions (European norm)
- EN 527-2:2002 – Office furniture. Work tables and desks. Part 2: Mechanical safety requirements (European norm)

Following the provisions of these standards, the designed work desk will have proper dimensions and relationships among dimensions, adequate functionalities and ergonomics and will provide the users with a safe interior environment (e.g. proper supports, proper distribution of load, positioning of joints and accessories, etc.).

In this case, *durability and serviceability* have been implemented by using a standardized and simple parts and a reduced number of technological operations, along with durable materials with a long useful life and easy to clean and maintain. In this way, the product is a demonstration of the guidelines of the Design for X approach, where X is replaced here no only by durability and serviceability, but also by quality, cost, manufacturability and ease of assembly. The details of these combined approaches can be better observed in the bill of materials (BOM) (Table 2):

Table 2

Bill of materials for the proposed desk

Nr. crt.	Name of component	Material	Dimensions	No. of pieces
1.	Large table top	Melamine	1100x 700x 18	1
2.	Small table top	Melamine	400x 700x 18	1
3.	Corner table top	Melamine	500x 700x 18 (rounded 500)	1
4.	Legs of table	Melamine	600x 732	4
5.	Metallic leg	Chromed metallic	732x 60 diam	1
6.	ABS	Plastic	2mm thick	
7.	ABS Adhesive	Adhesive		
8.	Bungs	Wood	6,5x 5 diam	Approx. 30
9.	Screws	Metal	10x 2.5 diam	4
10.	Connecting element (table1)	Melamine	864x 200x 18	1
11.	Connecting element (table 2)	Melamine	364x 200x 18	1

The *aesthetics* of the product are simple and lean, in accordance with the customers' requirements and current trends, without being the defining feature of this product. It has been positioned from the beginning as a work desk, for the average office worker, or, maybe, for some home office use. As such, it does not have significant image related roles. However, it projects a sleek, modern and discreet look that can make it attractive to a large customer base, while at the same time leaving room for the user to customize it in use according to their own wishes (Figure 4).

Fig. 4. Studies concerning the possible final aspect of the desk (w/o the roll box)

The *perceived quality* in the case of the studied product has been assessed during a focus group with 10 natural persons, possible customers of the given product, that have not been involved in the customer requirements gathering or other development phases. Their feedback is summarized in the table below based on a questionnaire with 10 items, 9 with a Likert scale and 1 open, aimed at determining strong and weak points of the proposed design and the drivers of the purchasing decision (Table 3):

Table 3

Summary of customer feedback regarding perception of the proposed desk

Nr. crt.	Investigated aspect	Responses
1.	Useful space and its distribution	0%-insufficient, 10%-barely enough, 80%-adequate, 10%-a bit large, 0%-too large
2.	Storage capacity	30%-insufficient, 40%-barely enough, 30%-adequate, 0%-a bit large, 0%-too large
3.	Flexibility of the arrangement	0%inflexible, 30%somewhat flexible, 70%-flexible enough, 0%-too flexible, 0%-unusable
4.	Perceived support and stability	0%-unstable, stable enough, adequate support, very stable, 0%-immovable
5.	Connectivity, adequacy for equip.	80%-no connectivity, 20%-low connectivity, 0%-adequate connectivity, 0%-high connectivity, 0%-very high connectivity
6.	Aspect, customization possibilities	0%-unlikeable, 10%-tarnished, 30%-acceptable, 50%-good looking, 10%-great looking
7.	Overall product evaluation	0%-poorly designed, 10%-acceptable, 20%-adequate, 50%-good, 20%-very good
8.	Desired product life	10%-under 3 years, 40%-3-5 years, 50%-over 5 years
9.	Other desired features based on the presented design (open)	Power outlets, modularity, coffee mug area, storage trays pawls, roll box anchors, possibility to conceal/organize cables, more modern materials, more futuristic design
10.	Likeliness to purchase	10%-not at all, 10%-not likely, 60%-likely, 20%-very likely, 0%-for sure

Based on these responses and considering the development, production and marketing costs, the decision of the company's management leans towards producing the desk both as an on-demand item and as a series item. Also, improvement possibilities can be inferred from these responses.

4. Environmental measures for the product life

There have been identified *three main directions* for acting upon the product in order to increase its environmental compatibility with the current regulations and the expectations of the target markets (Table 4). Each of these directions can be solved with multiple solutions that have both positive and negative aspects. Without providing final solutions, the authors recommend that the company make the corresponding product development and manufacturing decisions from the combinations below, after performing a cost-benefit analysis, a trade-off analysis and possibly, after appealing to innovative solutions such as the ones provide by the application of the TRIZ method (Theory of Inventive Problem Solving).

Table 4

Environmental planning for the proposed desk

Studied issue	Solutions	Challenges
Materials used and sustainability of resources	Eco-friendly particle board Use of recovered materials Replacement materials (plastics)	High price, customers will refuse Raises aesthetic and durability issues Cheap look and feel of the product
Interactions with environmental factors (mainly air)	Classic laminated surface Glass/Plexiglas covering Chemical treatments	Cheap look, poor product image Additional weight, sensitive Additional costs, possible side-effects
Recyclability at the end of active life	Particleboards, edges, adhesives Metallic components	Difficult to recycle, expensive to dispose Easy and cheap to recycle

A possible way out of this conundrum that balances the entire customer oriented development against societal issues would be to create a family of products, where different variants can be created by the clients themselves, thus encouraging them to be co-creators.

5. Conclusions

The product used in this case study, a work desk, has both residential and business viability, with minimal modifications or variations. It is essential that it is designed and manufactured in conformance with way the customer perceive an innovative, high quality and environmental friendly product, as they will spend considerable time working on it and it will be featured in their relationships with other persons (family, co-workers, customers). Our demarche showcases that by using proper scientific approaches and tools, as well as adequate software tools, a simple product (work table) can be transformed into a real partner for the customer (work desk). In this way, the quality of their working indoor environment is constructed by achieving the perception of satisfaction on the part of the customer, along the entire

work day and by minimizing potential negative impacts of poorly designed furniture (strains, aches, lack of functionality, air contamination, dissatisfaction, etc.).

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