

PAPER • OPEN ACCESS

## Elaboration of the initial requirements in the design activities

To cite this article: L Slătineanu *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1037** 012002

View the [article online](#) for updates and enhancements.

You may also like

- [Parameterized reinforcement learning for optical system optimization](#)  
Heribert Wankerl, Maike L Stern, Ali Mahdavi et al.
- [Inverse design of electromagnetic metamaterials: from iterative to deep learning-based methods](#)  
Chen Ma, Zhenyu Wang, Hui Zhang et al.
- [Optimal solution of engineering design problems through differential gradient evolution plus algorithm: a hybrid approach](#)  
Muhammad Farhan Tabassum, Ali Akgül, Sana Akram et al.



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Elaboration of the initial requirements in the design activities

**L Slătineanu<sup>1</sup>, B Oroian<sup>1</sup>, I Condrea<sup>1</sup>, C Botezatu<sup>1</sup>, A Hrițuc<sup>1</sup>, M A Boca<sup>1</sup>, M Coteață<sup>1</sup> and O Dodun<sup>1</sup>**

<sup>1</sup> Department of Machine Manufacturing Technology, “Gheorghe Asachi” Technical University of Iași, Blvd. D. Mangeron, 700050 Iași, Romania

Corresponding author's e-mail: hrituc.adelina3295@yahoo.com

**Abstract.** In solving the design problems, the initial requirements' clear statement significantly affects the design process's final result. Right from when the design problems are identified, the main requirements must be defined so that the final product meets the designed equipment requirements. Designers noted that design requirements do not have equal significance, and different solutions have been proposed to consider their weight in terms of end-use properties. The weighting can be achieved by simpler and operative methods and by more detailed methods of analysis. The paper approaches the problem of using the double input matrix method for weighting the functional requirements when discussing the problem of designing equipment to investigate the behavior of a computer component when the environment temperature is different compared to the normal temperature. The functional requirements assessment could provide an overview of the financial resources that could be invested in components to adequately meet the functional requirements. A first version of the tracked equipment was designed so that the previously established functional requirements are met.

## 1. Introduction

In machine building, *the design process* refers to the way of solving a technical problem. The researchers have distinct opinions concerning the stages of the design process.

Thus, when evaluating the design activity as an innovation process, 7 steps could be highlighted (identify the client need, researching the problem, brainstorming possible solutions, selecting a promising solution using the engineering analysis, achieving and testing a prototype, improving and redesigning/manufacturing the product) [1].

Other opinions could consider the four groups of activities within the so-called rational model: the pre-production design, the design during production, the post-production design, and the redesign [2].

The majority of opinions concerning the design process's definition considers an early step when based on the client's needs, the design process's goals are stated.

In such a stage, the client needs must be examined to define the functional requirements subsequently. Usually, the client's needs are expressed. The client desires a product or a process that allows him to achieve another product or process. In this stage, the designer must be clarified about what the client needs, and he must state the functional requirements so that the final product or process satisfies the client's desires.

On the other hand, when the final product or process includes known components and functions, there is a *routine design*, and when we have a new or at least improved product or process, there is a *creative design*. Over time, the evolution of human society showed the importance of creative design to improve the quality of life.



In such conditions, it is necessary to highlight the importance of establishing adequate functional requirements and even their selection that all the client needs be met - however, the product must be achieved quickly and at the lowest cost. One of the conditions to be met by the future product could refer to the product quality; we will understand that the future product must have such characteristics to satisfy the client's needs.

Within the so-called axiomatic approach of the design activity or *the axiomatic design*, the functional requirement must be defined according to the client's needs. It is necessary to highlight that there are functional requirements and, on the other hand, constraints or restrictions.

Professor Nam Suh considers that the functional requirements are a minim set of independent requirements that fully describe the functional needs of the product in the functional field. On the other hand, professor Nam Suh defines the constraints as bounds for acceptable solutions. There *are input constraints*, valid for the design specifications and *system constraints*, that refers to the conditions imposed by the system in which the future product must be integrated [3].

*The requirements engineering* concept was introduced to define, document, and maintain requirements during the engineering design activity.

Nuseibeh and Easterbrook proposed a roadmap to approach the requirements engineering [4]. They considered that the adequate establishment of the requirements would continue to play a significant role in generating a project's success or failure. They also formulated opinions concerning the future evolution of the research in the field of requirements engineering.

Martin et al. compared the requirements engineering process applied in two companies, considered the literature's models, and appreciated that no model corresponds to every project context [5]. They concluded that a requirements engineering process could combine linear and iterative structures, but the model could be appreciated as generally linear until the prototyping phase.

Socaciu and Blebea considered that a specifications document could clearly define the future product's requirements, and this document will be one of the documents for product development [6]. They showed that during software development, the requirements could be affected by changes due to the encounter of unforeseen situations. A general image concerning the so-called *field of requirements engineering* is addressed in the paper developed by these authors, including the various activities specific to this field.

Marcelino-Jesus et al. proposed a requirements engineering methodology to evaluate companies' technological innovation [7]. They appreciated that using such a methodology, an increase of acceptance of the companies' entrepreneurship initiative, and collaboration among enterprises are possible.

After establishing the functional requirements, a general defining of the product components and finding adequate solutions for them develops. Such an activity can be preceded or combined with an information activity to outline the best solutions to the addressed problem.

Due to the shorter time available, the information activity could be reduced or removed in routine design. However, if it is a creative design, the designer must resort to a selection process when determining each component of the final assembly or even the final assembly.

A problem of optimizing could be thus approached. Essentially, *the optimization* supposes the selection of certain versions among many available versions and using one or many selection criteria.

The problem addressed in this paper concerns the weighting of the functional requirements, starting from the fact that not all the functional requirements are of the same importance.

## **2. Use of methods of weighting the functional requirements**

As mentioned above, not all the functional requirements are of the same importance. For this reason, the attention directed by the designer to the statement and the ways of achieving the functional requirements could not be of equal importance.

The need for weighting the functional requirements could be thus approached. The methods applied to weight the functional requirements could be the same or similar to those used in the optimization processes. It is known that the optimization process is connected with the field of decisional analysis.

Taking into consideration the circumstances in which a decision is established, it is possible to classify the methods of decision making:

- Methods applied in certitude conditions;
- Methods used in the risk conditions;
- Method applied in incertitude conditions.

Some methods from the first group of methods (applied in certitude conditions) could inclusively weigh the functional requirements.

Such methods could be the double input matrix method, the pairwise comparison matrix method, the analytic hierarchy process method, etc. [8].

### **3. Use of the double input method to weight the initial design requirements**

One of the innovations resulted from the doctoral research was finding a solution to test a computer component's behavior when the working temperature is higher or lower than the normal temperature (for example, 20 °C).

As a component of the computer to be tested, the hard disk was selected. The choice was determined by the existence of specific software able to be used to evaluate the reading or the writing speed of the hard disk.

The initial idea was to use or to adapt a refrigerating box. Other functional requirements were formulated considering such an idea. A list of the main identified functional requirements found in the sequence of the conceptual design was the following:

1. Maintain a constant temperature inside the box;
2. Ensure a low temperature in the box;
3. Provide a working temperature higher than normal temperature (20 °C) in the box;
4. Provide easy insertion, extraction, and positioning of the computer component inside the box and quick connection of the computer component to the computer found out of the box;
5. Provide the possibility of relatively simple connection/disconnection of a heating device (with electrical resistance) found inside the box to a power supply source;
6. Ensure the operation of the cooling-heating subsystem until a preset temperature is reached;
7. Provide additional cooling to the cooling due to the cooling subsystem of the box, so when the latter does not provide sufficient cooling;
8. Ensure the highlighting of the values of temperature and humidity inside the box;
9. Ensure the box lid is sealed tightly.

If the design is deeper analyzed, other functional requirements could be identified.

In the next stage, the problem of weighting the identified functional requirements was formulated. If the double input matrix method is applied, a double input matrix must be considered, as the method name shows. This matrix's image could be seen in Table 1.

Such a table could also be used when establishing the value of the different equipment components to adequately allocate financial resources intended to be spent to obtain each equipment component.

As a result of information activity developed when identifying the functional requirements and including various results in the table, it was found that there are boxes able to refrigerate and heat the object found inside them.

In this way, some of the functional requirements are fulfilled by the same practical solution. In the axiomatic design, when some functional requirements are not independent, the design methodology (axiomatic design) requests actions to improve such a situation.

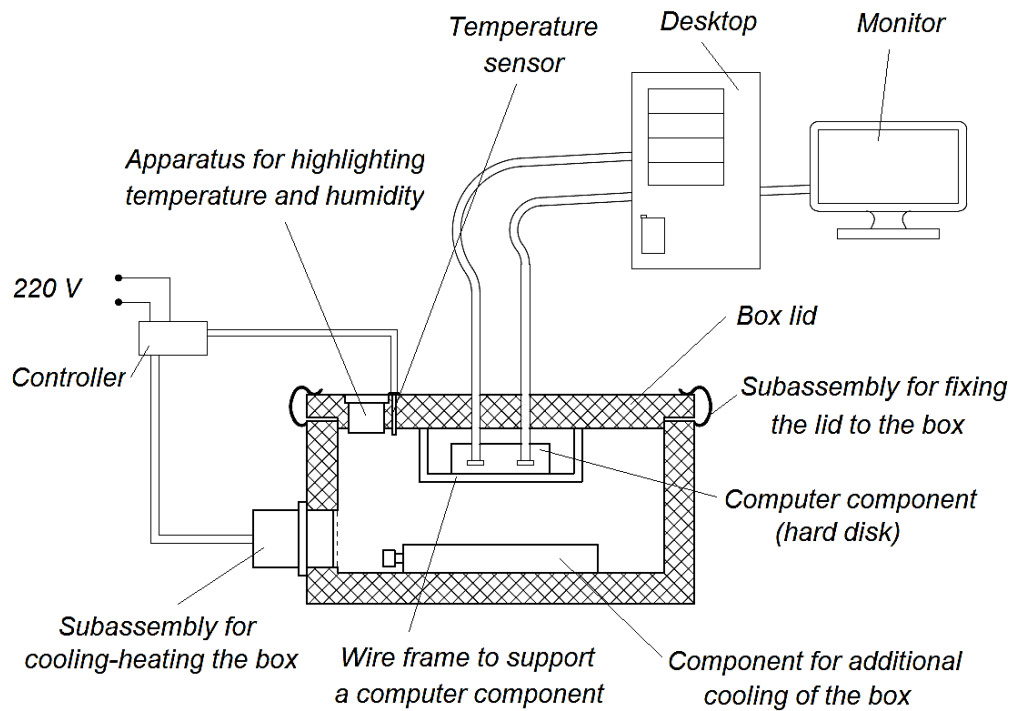
Also, during the short information activity, it was found that sometimes, the available refrigerating boxes do not ensure low enough temperature.

An additional solution to help decrease the box's temperature must be found to solve this new problem.

**Table 1.** Use of the double input matrix method to evaluate the functional requirements of the desired equipment.

| Functional requirements  | 1. Constant temperature   | 2. Low temperature | 3. Higher temperature | 4. Easy component insertion | 5. Simple connection/disconnection of the heating device | 6. Reach a preset heating temperature | 7. Additional cooling | 8. Highlight the temperature and humidity | 9. Tightly closing | Proposed problem solving  |
|--|---|--------------------|-----------------------|-----------------------------|--|---------------------------------------|-----------------------|---|--------------------|---|
| 1. Constant temperature  | X   | 0.5                | 0.5                   | 1                           | 1  | 1                                     | 1                     | 1   | 0.5                | Insulating box  |
| 2. Low temperature   | 0.5   | X                  | 0.5                   | 1                           | 0  | 1                                     | 1                     | 1   | 1                  | Refrigerating box   |
| 3. Higher temperature  | 0.5   | 0.5                | X                     | 1                           | 0.5  | 1                                     | 1                     | 0.5                                       | 0                  | Refrigerating/heating box   |
| 4. Easy component insertion  | 0   | 0                  | 0                     | X                           | 0  | 0                                     | 1                     | 1   | 0                  | Wireframe attached to the box cover   |
| 5. Simple connection/disconnection of the heating device                                       | 0   | 1                  | 0.5                   | 1                           | X  | 1                                     | 1                     | 1   | 0                  | Connection cables that cross the box lid  |
| 6. Reach a preset heating temperature  | 0   | 0                  | 0                     | 1                           | 0  | X                                     | 1                     | 1   | 0                  | Temperature controller  |
| 7. Additional cooling  | 0   | 0                  | 0                     | 0                           | 0  | 0                                     | X                     | 1   | 0                  | Passive cooling boxes   |
| 8. Highlight the temperature and humidity  | 0   | 0                  | 0.5                   | 0                           | 0  | 0                                     | 0                     | X   | 0                  | Devices for measuring and highlighting the temperature and humidity, mounted in the lid of the cold box |
| 9. Tightly closing   | 0.5   | 0                  | 1                     | 1                           | 1  | 1                                     | 1                     | 1   | X                  | Sealing gaskets and device for pressing the lid on the refrigerator box                                 |
| Sum $S_i$ of marks   | 1.5   | 2.0                | 3.0                   | 5.0                         | 1.5  | 4.0                                   | 7.0                   | 7.5                                       | 1.5                |   |
| Relative sum $V_{ri}$ of marks   | 0.041   | 0.055              | 0.083                 | 0.138                       | 0.041  | 0.111                                 | 0.194                 | 0.208                                     | 0.041              | S=912   |
| Order of the functional requirements taking into consideration the sum of their relative marks | 8 (highlight the temperature and humidity) - 7 (Additional cooling) - 4 (Easy component insertion) - 6 (reach a preset heating temperature) - 3 (Higher temperature) - 2 (low temperature) - 1 (constant temperature) - 5 (simple connection/disconnection of the heating device) - 9 (tightly closing) |                    |                       |                             |  |                                       |                       |   |                    |   |

After including the double input matrix's functional requirements, each functional requirement's comparisons with the other functional requirements must be made. A simpler result of the comparisons activity could facilitate the inclusion in the table of scores (marks) of 1-0 when the first requirement is considered more important, 0-1 when the second requirement is evaluated as more important, and 0.5-0.5 when two requirements are considered of equal importance. There is still the possibility to consider a more detailed evaluation of the functional requirements, for example, giving marks between 1 and 10 to each functional requirement. However, in Table 1, the simpler evaluation method was preferred.



**Figure 1.** Schematic representation for equipment of investigation the behavior of the computer subsystems when the temperature is lower or higher than the normal working temperature

Both in the first column and the first line of the matrix, the main functional requirements identified were included; since sometimes the full name of the requirement is long enough, abbreviated forms of the proper requirements (mentioned above) were used.

The mark will be so included in the table that the sum corresponding to each functional requirement could be calculated and inscribed in the table's antepenultimate line along each vertical column. In the ultimate line, the relative value  $V_{ri}$  of each functional requirement could be introduced. This relative value could be determined by devising the sum  $S_i$  of the marks given to each functional requirement to the total number of the comparisons  $N_c$ :

$$V_{ri} = \frac{S_i}{N_c}, \quad (1)$$

where

$$N_c = \frac{n(n-1)}{2}, \quad (2)$$

where  $n$  is the number of functional requirements.

In the analyzed case,  $N_c = 9 \cdot 8 / 2 = 36$ .

A new order based on the evaluation of their significance could be identified. This order is highlighted in the ultimate line of Table 1, considering the sum of the relative sum  $V_{ri}$  of each functional requirement. Afterward, adequate solutions must be found to fulfill each functional requirement, and the first identified versions were included in the last column of Table 1.

It can notice that the most important functional requirement seems to be highlighting the temperature and humidity. The lowest weight was given to the necessity of tightly closing the refrigerating/heating box. A first version thought considering the proposed solution to fulfill the functional requirements can be seen in Figure 1.

#### 4. Conclusions

The establishment of the design engineering requirements can exert a decisive influence on the evolution of product development. Over the years, the researchers formulated different opinions about solving the problems specific to elaborating on the design requirements. It has been noticed that not all the functional requirements are of equal significance. A weighting method could be used to order the functional requirements considering the sum of their relative marks. An application of the double input matrix method in the case of equipment for investigation of the computer subsystems behavior at the changing of the working temperature was developed. Adequate initial solutions for each functional requirement were identified. It noticed that while establishing the functional requirements, improved versions of requirements and solutions for their solving were found. In the future, there is the intention to apply more detailed analysis methods to weigh the functional requirements valid in the case of research or industrial equipment.

#### 5. References

- [1] Hands-on Activity: Design Step 1: Identify the Need 2016 [https://www.teachengineering.org/activities/view/cub\\_creative\\_activity1](https://www.teachengineering.org/activities/view/cub_creative_activity1) Accessed 28.03.2020
- [2] Hiwase S D 2016 [https://www.researchgate.net/publication/305724231\\_Product\\_Design\\_-\\_Innovative\\_Trends\\_on\\_Design\\_Philosophies\\_Approaches\\_Processes\\_Techniques\\_Methods\\_Standards](https://www.researchgate.net/publication/305724231_Product_Design_-_Innovative_Trends_on_Design_Philosophies_Approaches_Processes_Techniques_Methods_Standards). Accessed 26.09.2020
- [3] Suh N P 2001 *Axiomatic Design: Advances and Applications* (New York: Oxford University Press)
- [4] Nuseibeh B, Easterbrook S 2000 *ICSE00: 22nd International Conference on Software Engineering* (Limerick, Ireland) pp 35–46
- [5] Martin S, Aurum A, Jeffery R, Paech B 2002 *Proceedings of 7<sup>th</sup> Australian workshop process models in practice. AWRE'2002* (Melbourne, Australia) pp 141-155
- [6] Socaciu L G, Blebea I 2010 *Proceedings of the 10<sup>th</sup> National Multidisciplinary Conference with international participation "Professor Dorin Pavel - the founder of Romanian hydropower"* (in Romanian) vol 17 (Sebeş, Romania: Publishing House AGIR) pp 47-54
- [7] Marcelino-Jesus E, Sarraipa J, Agostinho, C, and Jardim-Goncalves, R A 2014 *Proceedings of the 21st ISPE Inc. International Conference on Concurrent Engineering, CE 2014* (Beijing, China: IOS Press BV) pp 577-586
- [8] Slătineanu L 2019 *Fundamentals of scientific research* (in Romanian) (Iaşi – Romania: PIM Publishing House)