MINISTERUL EDUCAŢIEI NAŢIONALE
ROMÂNIA
UNIVERSITATEA DE MEDICINĂ, FARMACIE, ŞTIINŢE ŞI TEHNOLOGIE „GEORGE EMIL PALADE" DIN TÂRGU MUREŞ

Acta Marisiensis. Seria Technologica
Vol. 21 (XXXVIII) no. 1, 2024
ISSN 2668-4217, ISSN-L 2668-4217

ASPECTS REGARDING THE CONCEPTUAL OPTIMIZATION OF DESIGN AND PROTOTYPING MANUFACTURING

Bogdan BUCUR[1]

1,George Emil Palade University of Medicine, Pharmacy, Science and Technology of Targu Mures

Gheorghe Marinescu, 38 Tg.Mures 540142, Romania
[1]bogdan.bucur@umfst.ro

Abstract

Every product initially starts with a creative idea, more or less feasible, or a patented idea transformed into a finished product. This idea takes shape through a market research study. These studies of analysis and needs present technological opportunities while outlining step by step the concept-prototype version. Thus, based on computer-assisted simulations, the prototype is once again subjected to a systemic analysis to define and optimize the final product, as well as the technological flow associated with the entire manufacturing process applied to the concept.

The paper proposes a synthesis analysis regarding innovative conceptual design, also presenting a case study applied to a product that involves a new concept in the market, specifically a decorative element, an ornament for doors (shield), so that the door handle matches the door's style

Key words: prototyping concept, 3D modeling, design, 3D print manufacturing

1. Introduction

Conceptual engineering or conceptual innovation design can be described as a set of decisions made to meet specific product-related requirements. In the product development process, there are several stages: idea generation, product definition (also known as product planning), conceptual design, detail design, and functional design, as well as simulation, prototyping, manufacturing, and testing. Design is an omnipresent and highly valued activity for the consumer base, designers, and in terms of competitiveness. Designers benefit from sophisticated conceptual tools, combined with the creativity of conceptual ideas that materialize using various processes, methods, and advanced design principles to develop an innovative concept right from the initiation stage, starting from an idea and defining the entire technological process step by step towards the finalization of the innovative product concept in the prototype phase. The definition of the method and working principles is determined based on the product's typology and use. These aspects are systematically analyzed using a general structure of ideas, which are subject to dissemination and the definition of conclusions to subsequently enable the establishment of directions for computer-aided design, simulation, manufacturing, and final testing of the prototype concept.

All of these stages are encompassed in the product life cycle diagram, which includes the following stages: documentation, prototyping, market launch, development, maturity, and decline. [1,2,3].

Engineering thinking defines a structured analysis of ideas associated with the structure of the product design process under consideration. The analysis structure is presented in Fig 1.

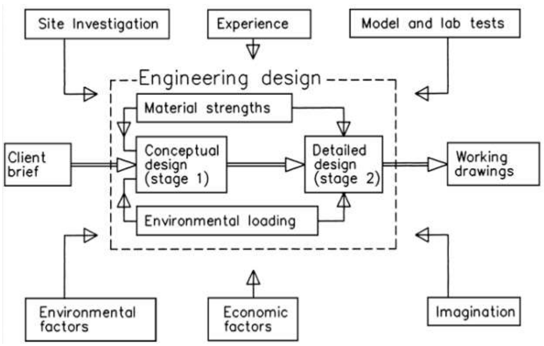


Fig. 1: Product Planning [6]

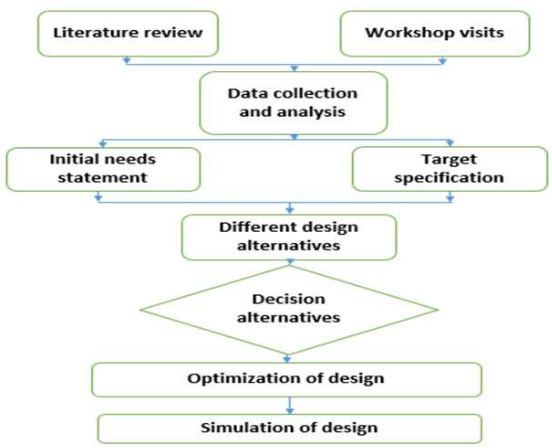


Fig. 2: Decision analysis [6]

Creativity is a complex capacity. It enables the creation of tangible or purely mental products, representing progress on a societal level. The primary component of creativity is imagination, but the creation of real value also presupposes motivation, the desire to achieve something new, something exceptional. Creativity has been defined as an interpersonal or intrapersonal process whose outcome consists of original, significant, and high-quality products.

The conceptual design phase is the most important phase in concurrent engineering after the project planning or product definition phase. Approximately eighty percent of a product's life cycle costs are incurred through systemic analyses and design solutions, such as material selections and manufacturing processes in this phase. Conceptual design involves defining, exploring, evaluating, and selecting the concept [1,4].

The product design criteria include functionality (a component consists of various parts. The functional part is the one that truly has a critical assignment leading to the component's performance. The non-functional part does not play a major role in the product's existence but is related to maintenance, coverings, inspection, and aesthetic value and must be minimized to achieve low production costs, [7]. The product's uniqueness is defined by manufacturing issues, complexity, material selection and definition, dimensional accuracy, tolerances, surface finishing, surface treatment, process cost, resulting waste, handling, and assembly. All these analysis stages can be encompassed as early as the design phase through simulations and addressed situational analyses, as shown in Fig. 2.

Innovation in concept development is defined and constituted by three main innovation processes:

1. The process of creating knowledge from public or industrial research.
2. The process of developing the new product, which transforms knowledge into a new product.
3. The product's success in the market, which depends on the product's functionality and the organizational competencies of the company to produce them at a reasonable price and quality, as well as appropriate market orientation.

2. Research Methodology

Innovative ideas are primarily generated from user comfort and ergonomics or from a unique situation, starting from a study based on marketing functions, [6], as shown in Fig. 3.

Following the research study regarding project development alternatives and methods, options may include brainstorming, the method of discard and vote (D&R), or the designer's intuitive skills to choose the most feasible and efficient alternative to best meet customer needs. The selection of the best alternative was made using the weighted scoring matrix of engineering design.

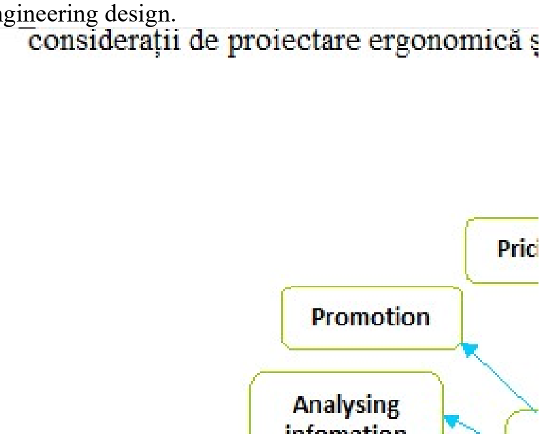


Fig. 3: Marketing Functions [6]

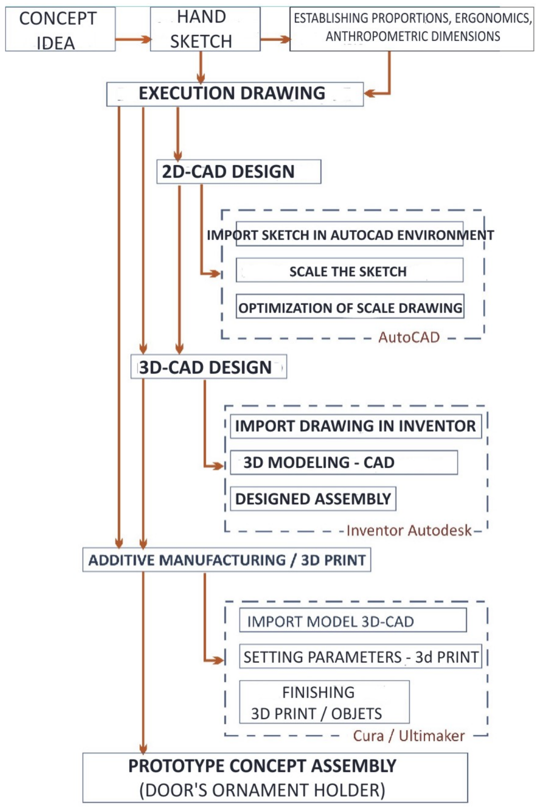


Fig. 4: Block diagram of Systemic Analysis

Innovative ideas are primarily generated from user comfort and ergonomics or from a unique situation, starting from a study based on marketing functions, [6], as shown in Fig. 3.

Following the research study regarding project development alternatives and methods, options may include brainstorming, the method of discard and vote (D&R), or the designer's intuitive skills to choose the most feasible and efficient alternative to best meet customer needs. The selection of the best alternative was made using the weighted scoring matrix of engineering design.

Factors to consider include ecological design concepts, efficiency, ergonomic and safety design considerations, aesthetics, and well-defined proportions, among others, [2,3]. All these marketing analysis functions must be taken into account for the development of the innovative structure of the product under consideration.

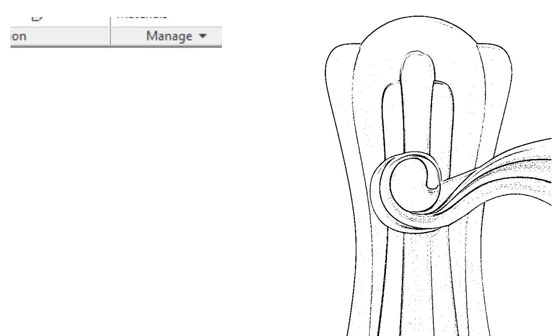
This work proposes the definition of a structured idea analysis model for initiating an innovative concept, aiming to define a working method for idea generation. The paper presents a case study that identifies an innovative solution by analyzing technical solutions through a multidisciplinary approach from simple to complex. The proposed method involves the assimilation and development of new creative skills, the stimulation of curiosity, and the motivation of aesthetic senses to provide an efficient direction in the design and manufacturing of industrial products. By combining creativity with unconventional technology, the goal is to develop harmoniously integrated concepts from both an aesthetic and functional perspective.

The semantic approach of the working methodology [8] is achieved through a gradual transition from the idea to the graphical representation of a hand-drawn sketch, to the representation and modeling to scale of materialized objects based on hand-drawn sketches using digital programs and technology, and finally, the production of the entire assembly in physical format is proposed. In Fig. 4, a systemic analysis block diagram of the approach methodology is presented, defining the work stages, as analyzed in the proposed case study.

Hand Sketch

Represents the initiation and transposition onto paper of the graphic elements that implicitly define the creative idea of the door ornament (the considered product) and allow the subsequent realization of the project, while also analyzing proportion, aesthetics, and ergonomics applied to the proposed concept. Following a synoptic analysis of the sketch, the dimensions for the geometric elements defined graphically are identified.

In Fig. 5, the hand sketch is identified, defining the overall geometric line and shape on which the project is structured. The geometric curves are freely represented to configure the semantics of the assembly into a well-defined aesthetics and harmony for the intended purpose.



a. b.

Fig. 5: **a**. Detail of a classic door ornament, **b**. Hand-drawn sketch of the proposed ornament

Ergonomics and Proportion

The overall dimensions, labeled with capital letters on the manually drawn sketch, subsequently identify the analysis and synthesis of dimensional proportions for each reference point, as well as the ergonomics of the assembly correlated with the technical anthropometry specific to the consumers' dimensions.

Technical anthropometry aims to meet the consumer demand of various ages to be able to grasp objects, and their dimensions should be integrated into the comfortable dimensions of the objects, also providing them with a dynamic operability character through the applied design details to ensure optimal dimensional adaptation [12].

Assisted 2D / CAD Design

In this stage, the dimensional details of the sketched concept are established implicitly, based on a scan or photocopy of the hand-drawn sketch (the sketch is executed at an approximate scale). The scanned document is imported into the AutoCAD design environment, as seen in Fig. 6.

The working procedure goes through the following stages:

- Scanning and importing the hand-drawn sketch into the AutoCAD environment.
- The dimensional position 'A' or 'B' is defined, and by identifying the ratio between the scaled value and the value for dimension 'A,' a unitary or subunitary ratio is identified, called the scaling factor. Its application defines the scanned sketch to the desired size, and all dimensions are reconsidered proportionally.
- The geometric elements presented in the section are redrawn on a different layer, obtaining the main dimensions of the concept's assembly.
- For each part identified in the main section, the geometric elements represented to scale are extracted, and subsequently, profile drawings and dimensions are defined for each reference, as well as the door ornament and handle assembly.
- In the end, all parts are represented to scale.

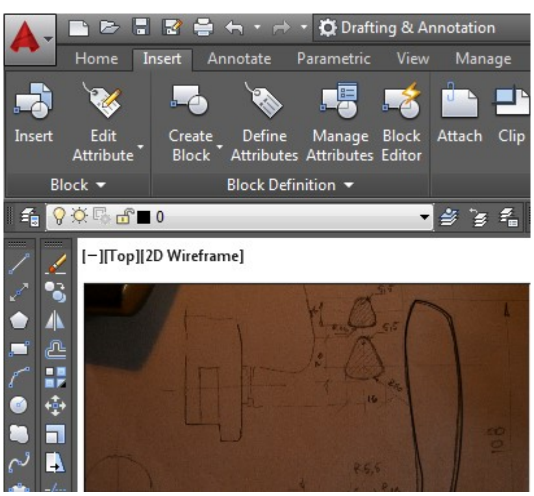


Fig. 6: The AutoCAD environment: Defining geometry and ergonomic dimensions / door handle [5]

The 2D design of the assembly of parts represents the preparatory part for parametric (3D) modeling of the parts in the next stage. For better optimization of work in the AutoCAD environment, a different layer is defined for each part.

In this synthesis stage, all geometric elements are analyzed and defined, curvilinear elements are corrected, and thicknesses, dimensions, and dimensional ratios are adjusted.

Parametric 3D / CAD modeling

Preparing the 3D design environment identifies a working file 'project' that allows automatic saving of all modeled parts. In the event that diversification/modification of the parts is desired, it can be done in an optimized manner, depending on the constraints associated with the parts in the assembly.

The Inventor design environment is compatible with AutoCAD, simplifying the working procedure for each component part in the sketched assembly.

The advantage of using the Inventor environment is that the 3D model can be parametric, allowing for product diversification based on dimensions, a feature not possible in AutoCAD. Importing from AutoCAD is done directly with the '.dwg' extension, and it is preferable for the selected profile to be in polyline form (a block of entities edited graphically).

Based on the profiles obtained from the previous stage, see Fig. 5.b, as well as adhering to the dimensions presented in the execution drawings, 3D models are defined in the Inventor environment, while respecting the geometry and dimensions established in the assembly.

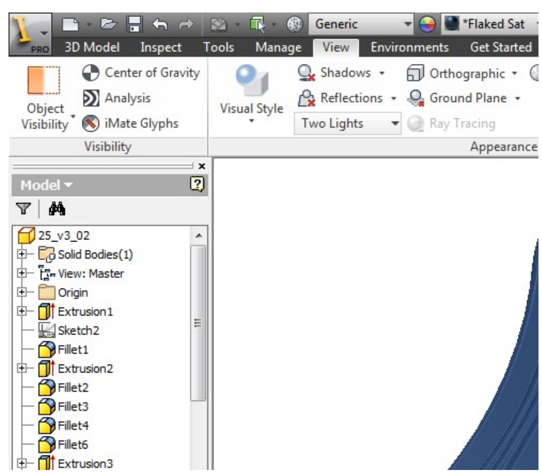


Fig.7: The Inventor environment: defining the 3D model / door's ornament holder

To obtain the 3D model, computer-aided design is used in a parametric environment, such as Autodesk Inventor. In this environment, the base sketch that defines the profile imported from the AutoCAD environment is identified. All dimensional constraints are defined, and in the 3D environment, the translation or rotation procedure is chosen for the defined profile, resulting in the final 3D object.

For the latch profile, the process is identical, and the geometry is imported from the AutoCAD environment into an axial plane of the initially generated 3D body. A new editing file is identified for each part. Once the component parts are completed, they can be assembled in the Assembly/Inventor environment, inserted and constrained to each other, resulting in the assembly shown in Fig. 7.

Additive Manufacturing

For the physical manufacturing of the entire designed and modeled assembly, additive fusion technology is used for each part considered, as shown in Fig. 8.

The finalized 3D models in the Inventor environment will be exported with the '.STL' extension to the CURA environment to establish 3D printing parameters for Ultimaker-type printers. For the working procedure, distinct parameters are defined, including:

• The orientation of the 3D model.

• Setting parameters related to the infill structure with interlayer filling density and extruder travel speed.

• Temperature adjustment is another important parameter that must be adhered to based on the type of filament used.

• The printing bed temperature setting is done according to the type of filament used.

• The choice of filament type: PLA/ABS, in different preferred colors.

• The 'G' code, an associated programming source for each 3D model part.

The completed project represents a creative learning exercise carried out in a team, with the aim of defining the stages and method underlying the optimized design of concept-prototypes. The realization of the assembly is done step by step to complete the project: starting from a hand sketch, creating a scale drawing to establish proportions in the AutoCAD environment, 3D modeling of each component in the Inventor environment, and setting the printing parameters in the Cura environment. Finally, the physical model of the printed assembly is created using Ultimaker printers.

3. Results

The work as a whole provides a new field of application for managing and deepening innovative conceptual design, as well as exploiting engineering management for the purpose of optimizing the synthesis of innovative concepts.

Keep in mind that the process of generating a concept idea may vary depending on the nature of the project or product, but these 13 steps can provide a structured approach to develop innovative ideas.

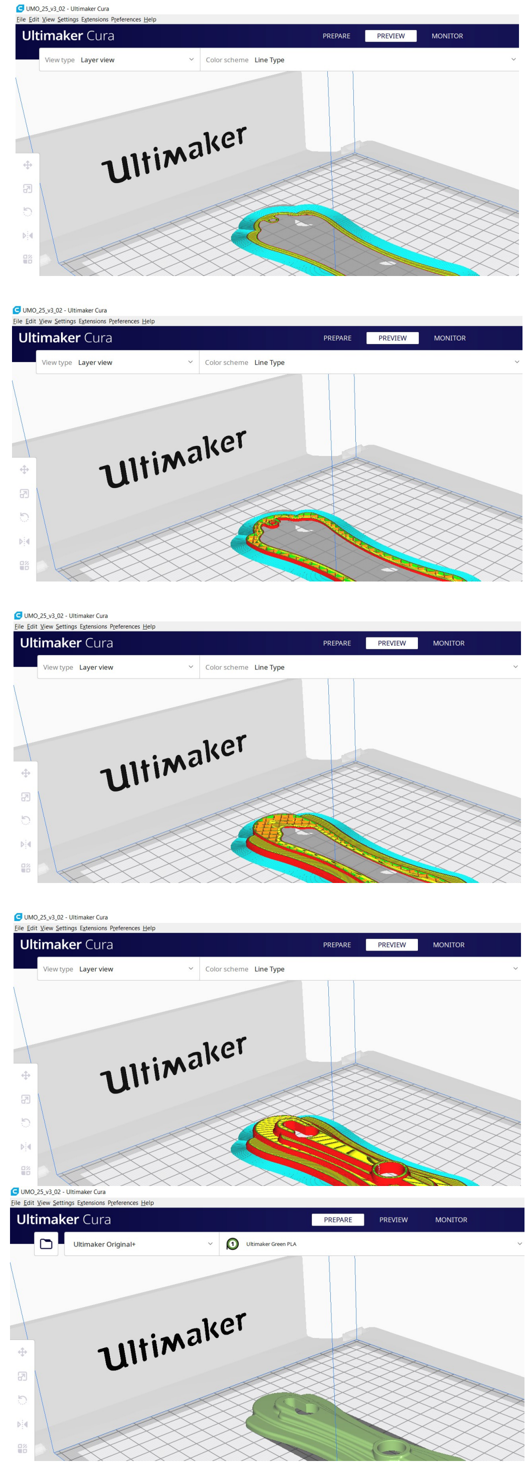


Fig. 8: The CURA Environment: Viewing of the working parameters (3D Print)

1. *Define the objective:* Start by clearly defining the goal or problem you want to solve. What do you want to achieve with this concept?

2. *Analysis method:* Gather a team and generate as many ideas as possible, regardless of how unrealistic or unconventional they may seem at first. Do not limit yourself in this stage.

3. *Research:* Study the field or relevant technology for the project and learn more about current trends and market needs.

4. *Inspiration:* Seek inspiration from various sources, such as books, magazines, exhibitions, websites, and even from nature or everyday life.

5. *Association and connections:* Try to connect the ideas you generated during the systemic analysis. What relationships can exist between them? How can you combine elements to create something new and innovative?

6. *Filtering:* After generating a list of ideas, start filtering them. Eliminate ideas that are not feasible or do not align with your objective.

7. *Development*: Work on refining and developing the selected concept idea. Detail how it could be put into practice.

8. *Feedback:* Obtain feedback from colleagues or experts in your field to improve the concept.

9. *Testing and adjustment:* Virtual simulations allow for the improvement of the designed prototype, providing the opportunity to test the prototype concept even in the CAD design phase. Adjust the concept based on the results obtained.

10. *Presentation:* Present the concept idea in a clear and convincing manner, whether it is to team members, investors, or anyone else who needs to approve it.

11. *Physical testing of the prototype*: Based on the resulting model, conclusions can be drawn regarding the improvement of the initially designed prototype.

12. *Refinement and Validation:* Continuously refine and adapt the concept based on feedback and insights. Confirm that the concept is aligned with the initial objective and is practical for implementation.

13. *Documentation:* Document the concept thoroughly to ensure that all team members understand and can work towards its realization.

Fig. 9: Final 3D print / assembled model

The process of generating a concept idea can vary depending on the nature of the project or product, but these basic steps can provide direction and structure for developing innovative ideas.

This paper has presented an integrated model of the creative innovation process, focusing on the aesthetic integration of products from the design phase and materializing it at the prototype level using unconventional rapid prototyping technologies in the development of the concept-prototype, you can see in Fig.9. The model follows a lifecycle approach from the initial idea to the exploitation of the new concept.

4. Conclusions

The purpose of this case study is not to provide academic proof of the methodology's validity but rather to gain practical experience and idea-generating sources for learning and deepening innovative technical solutions applied to products.

This paper has presented an integrated model of the creative design process while defining an original working method. In another sense, the model follows a lifecycle approach from the initial idea to the product's market launch. However, the work as a whole provides a new field of application for managing and deepening innovative conceptual design and exploiting engineering management to optimize the synthesis of innovative concepts.

References

1. Bogiano A., Achivement and motivation a social development perspective,Cambridge University Press, 1992;
2. Gardner, H., Creating Minds. An Anatomy of Creativity,Basic Books, New York, pp.19-48,50-86,87-131), 1993;
3. G. Butterworth and M. Harris, Principles of Developmental Psychology. Hillsdale, NJ: Lawrence Erlbaum, 1994;
4. Kroll, E. Innovative Conceptual Design: Theory and Application of Parameter Analysis. Cambridge University Press, 2001;
5. Bucur B., Tero M. Grafică inginerească cu AutoCAD, Ed. Știința, Chișinău, R. Moldova 2023;
6. Bucur B., Ban A., Vlase S., Modrea A., Creativity and generation of ideas in the design of children's toys, ISI FI 2.835, Children, 2023;
7. Bilén, Sven G. and Richard F. Devon, "Innovative engineering Design Education," International Conference on Engineering Design (ICED), Melbourne, August 15–18, 2005;
8. Santash J. Design creativity: refined method for novelty assessment, International Journal of Design Creativity and Innovation, vol 7, Issue 1-2 / 2018;
9. Kim, I.L., O.L. de Weck, W. Nadir, P. Young,

and D. Wallace, “Innovative Modern Engineering Design and Rapid Prototyping Course: A Rewarding CAD/CAE/CAM Experience for Undergraduates”, American Society of Engineering Education (ASEE) 2004 Annual Conference & Exposition, Salt Lake City, Utah, June 20–23, 2004;
10. French, M.J. *Conceptual Design for Engineers,* 1985 (The Design Council, London);
11. https://www.scritub.com/profesor-scoala/CREATIVITATEA-SI-MOTIVATIA-FAC35575.php;
12. https://en.wikipedia.org/wiki/Human_factors_and_ergonomics.

This work was supported by the University of Medicine, Pharmacy, Science and Technology „George Emil Palade“ of Târgu Mureș Research Grant number 163 /1/ 10.01.2023