POLITEHNICA UNIVERSITY OF BUCHAREST
FACULTY OF INDUSTRIAL ENGINEERING AND ROBOTICS

DOCTORAL THESIS
- SUMMARY -

Developments and contributions in the improvement of design assessment for industrial products

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Foreword

"Design is a conscious and intuitive effort to impose meaningful order", Papanek's [109] vison on design is the very premise from which this thesis starts, as a response to the perpetual question of why things are as they are, in such an attempt to find an algorithm for them. Of course, for the natural ones there has always been interest, such as sacred geometry starting from Euclid [45], which approached as early as 300 BC the initial concept of "golden ratio" based on a ratio analysis of the segments of the pentagram, concept later elaborated by Fibonacci [114] in the 13^{th} century and later in the 16^{th} century by Pacioli and Da Vinci [103] which introduce the idea of „divine ratio". Concerning the „human ratio", can we discuss a concept of the algorithm of anthropic things and how we relate to the goods used daily, since they are created by humans for humans? In this case, the human proportion could go beyond strictly relating to an anthropometric framework, all the more so as one can speak of the human capacity to perceive and generate patterns and their association with the concept of beauty [89], as is the case with visual harmony. Thus, in the case of a product it becomes problematic to what design must respond in the first place, of course being important the visual harmony as well as the technical or ergonomic one but how to establish which of them could have priority for a certain object? In this way the emblematic concept *„ form follows function"* arises from Greenough [56] analysing what prevails for a product as if it was approached on the basis of a scale of importance to its elements, how the practical purpose of the product overlaps with the fulfilment of other human needs at the top of the pyramid, especially if these items cannot be met independently? Is it sufficient to comply with technical restrictions and thus, what determines the final form of a product, could it be considered attractive only because it seems to fulfil its purpose well and at the same time to respect an algorithm of visual harmony without being necessary possible decorative elements? However, we cannot claim a form absolutely adapted to the purpose and we must determine where the line is drawn, as the product must primarily ensure all aspects necessary for the process of use and perform its function as well as possible, it must do everything what it promises and not only functionally, the promise must be kept by all dimensions of design, including symbolism and aesthetics, a superior product being represented by its real form in close relation to the degree of integrity associated with it. Moreover, wrongly, there is often a tendency to associate products defined by superior design to higher social classes, however the concepts of good taste cannot address only to the elite. Design has the responsibility to maintain the same form of integrity regardless the category to which it is dedicated, therefore the association with the idea of kitsch should be avoided regardless of user typology, where kitsch is not representative only for poorly made objects, often represented by non-original repetition of other concepts with the presence of clichés or becomes a form that desecrates recognized symbols [151], it is all the more important as it is not only a matter of ethics, but also of aesthetics [19], which is visibly reflected on design. Even assuming a grey line for the concept of kitsch, it is often overcome by generating playful products in the hope of gaining a form of competitive advantage and for products that want to be avant-garde there is a major risk of going to the other extreme if certain aspects are forced and tend to become kitsch and not innovative as desired. Thus it presents a form of delimitation for the term design, being essential to be separated from the unique or limited series products that are handmade, for these, the specific concepts being decorative art or handcraft [38] and in the present thesis design is associated with any product obtained as a result of an industrial process, thus called industrial design.

The term design is often surrounded by ambiguity and can even mean different things to different people [98], most often the design is associated with the appearance of the product, which makes a direct reference to the concept of aesthetics. However, how can the subjectivity often associated with art be intertwined with the pragmatic rules of technics without the subject of design itself becoming ambiguous? The way it is defined and understood also has multiple valences, in Romania being associated with “harmonization of the human environment” [166], “combining the beautiful with the useful” [167] or “the set of factors (...) which contributes to the appearance and quality of the high series product” [168]. According to the World Design Organization (WDO), industrial design represents a “strategic problem-solving process (...) leads to a better quality of life through innovative products, systems, services, and experiences” [169] and in the Encyclopaedia Britannica it is defined as “design of mass-produced consumer products” [170]. As can be seen, the concepts do not really contradict each other however they take into account different perspectives, being found on the other hand approaches to design as broad as possible [38, 47] which encompass the multitude of aspects presented. Thus, design is often found in a perpetual struggle between technics and aesthetics, especially since it is strictly related to sales and purchase decision, considering that it is the responsibility of aesthetics to attract customers and of technics to keep them, but aesthetics is not a dimension of a relative nature, although it is often erroneously attributed to buyers' preferences, this responsibility being the dimension of symbolism in relation to the considered segment. Moreover, the technics cannot be considered responsible for all the functional or ergonomic aspects that intervene in the user experience, as a durable product is not necessarily also easy to use. Considering these, it is the designers' responsibility to admit and be aware of all the implications that contribute to the final form of the product, a product that is designed to improve life, as reliability and quality cannot be associated with a product designed just to attract customers. Even in a society based on consumerism, a real delimitation of the concepts of buyer and user is necessary, understanding in depth the whole process of use and the quality associated with the product, in order to ensure a superior user experience. On a large scale, considering all of these aspects has the role of contributing to sustainability and, ultimately, to reducing the volume of waste. Since a sustainable product involves of course a longer lifespan [10], not surprisingly, its reliability issues are the main reasons why a product is replaced [149], reliability that, in turn, as we will see, is not only associated with the technical dimension.

The presented thesis thus aims to identify all the relevant aspects that could influence the final form of a product, considering how the assessment perspectives intertwine and could impact the product features down to the smallest details. In fulfilling this potentially elusive objective, to develop a holistic methodology in the design assessment of industrial products, on this occasion, I would like to thank those without whose support this paper would not have been possible. I would like to extend my deepest gratitude to Professor Constantin Militaru for the trust and support given throughout the entire activity of thesis coordination and to Professor Andrei Dumitrescu that represents a real mentor in the journey into the world of design and beyond, to whom I am fully grateful. I would also like to thank my family, starting with my father who made a major contribution in shaping my engineering skills, my mother for the support and superhuman determination instilled, my sisters who have constantly contributed to what I am today and last but not least, my life partner for the enormous help, support and patience he has shown over the years. Also, I would especially like to thank my grandfather, whose principles will always guide my life, to whom this thesis is dedicated to.

Author

INTRODUCTION

Starting from the subjectivity associated with industrial design, the purpose of this thesis is to develop a strategic approach of analysis that can be interpreted numerically regardless of the nature of the aspects considered in the assessment, which includes details both on functionality and also product aesthetics or user preferences. The method thus described is intended to assess the design of industrial products, considered in the paper as series products obtained from an industrial process, the concept of industrial design being considered as the set of factors that influence the structure of the product taking into account the destination of use and user typology, with the ultimate goal of associating quality for both the resulting product and the user experience itself.

Regarding the structure of the paper, the thesis was delimited in four parts, in the first part being presented the analysis of the current stage of the concept in which the current assessment methods were comparatively analysed both from the perspective of the method typology and the set of relevant criteria. Based on the analysis, the optimal assessment approach was identified and the criteria were structured in three categories, product features, analysis perspectives named in the thesis assessment dimensions and design attributes. As it has been observed that the three categories can influence each other and are implicitly interconnected, a new approach for the criteria has been proposed, a criterion representing the result of the correlation between a feature and an assessment dimension, to which an associated attribute corresponds. Due to the complexity of the resulting format, using the same criterion structure, two versions of application of the method were proposed, one in the standard version in which the criteria are interpreted as antagonistic attributes and an extended version involving additional studies for each criterion taking into account the set of factors that can influence the assessment of the criterion. Based on the current stage, in the second part of the thesis, the actual assessment structure was developed considering the stages of application of the method. Starting from the proposed pre-assessment study, the analysis perspectives for each criterion were presented together with the corresponding grading principles, finally being represented the determination process of the assessment indicators and results interpretation. In the practical contributions part of the thesis, considering three series of products, with the support of a local industrial goods producer, it was conducted a correlation study between commercial success in terms of sales volume and the values of design indicators obtained from the method application. Also, in order to reduce the difficulty of determining the assessment indicators, a web platform was developed in which the proposed method was implemented, thus automating the calculation steps, eliminating both the additional effort to apply the method and potential errors that may arise from incorrect interpretation of the data. In the last part of the paper the general conclusions of the study were presented and was described the way that objectives were met during the thesis, along with the original contributions and prospects for further development.

CHAPTER 1.

CURRENT STATE OF THE RESEARCH IN THE FIELD OF INDUSTRIAL DESIGN ASSESSMENT

Strongly correlated with the ambiguity associated to industrial design, its assessment has multiple valences depending on the perspective from which the product design is approached, finding discrepancies even greater as the areas of specialization of evaluators differ, as approaches and criteria considered in the technical design assessment are different from those in the design competitions that emphasize mainly on aesthetics or symbolism [36, 118], as the evaluator tends to pay attention to the details of his expertise [17]. Also, not only the considered criteria can make great differences in the design assessment perspectives, the specificity of the method being otherwise relevant [74], affecting the degree of objectivity associated with the method itself.

1.1. CLASSIFICATION OF ASSESSMENT METHODS

In order to structure the current approaches, the **author proposed** the following approach of organizing the design assessment of industrial products methods (described in the thesis along with the associated advantages and disadvantages and examples of the corresponding methods), based on five analysis perspectives with the corresponding proposed categories this way:

a) Depending on the applicability of the method, the two following categories are considered: comparative analysis methods and individual and potentially comparative analysis methods.

b) Depending on the type of assessment process considered in the method, the three following categories are proposed: methods based on visual analysis, methods based on tangible analysis and methods based on general-sensory analysis.

c) Depending on the type of data used in the assessment, the three following categories are considered: data-driven methods compared to analysis standards, methods using uncertain data and methods based on combined data.

d) Depending on the evaluator's level of expertise, the two following categories are considered: methods in which the assessment is performed by respondents and methods in which both the actual assessment and the interpretation of the data are performed by specialized evaluators.

e) Depending on the type of assessment elements, the six following categories are considered: methods related to product features, methods related to assessment dimensions, methods related to design attributes, user-centered methods, methods based on design-related elements and hybrid methods.

1.2. ANALYSIS OF CURRENT ASSESSMENT METHODS

According to the typology of assessment elements, among the approaches presented above, a series of hybrid - general methods were further analysed, as the development of a hybrid methodology associated with the general assessment of industrial product design is the main objective of this thesis, with the aim of encompassing all the essential aspects of the assessment. Thus, a number of hybrid methods were analysed [75, 78, 105, 110, 122, 144 152, 159, 164] and were approached comparatively, identifying notions regarding the specificity of the approach, the type of assessment approach and the typology of the elements together with the extent to which they are considered in the method, all these notions having the role of establishing the delimitation framework for the method that is to be developed. Thus, the current stage analysis was performed to identify the weaknesses as well as the strengths of current techniques, along with establishing all the relevant elements associated with a design assessment method that is intended to be holistic.

1.3. ANALYSIS OF ASSESSMENT CRITERIA

Starting from the purpose of the previous analysis to better understand the hybrid assessment methods by their structure and their elements, in order to determine the typology of the criteria used in the design assessment, the elements on the basis of which the actual assessment is performed were also analysed, considering the specific criteria of the hybrid methods analysed previously, together with additional perspectives for approaching the criteria [14, 36, 44, 128, 154, Paper 2], proposed in studies of design assessment and determination of relevant criteria.

CHAPTER 2.
ESTABLISHING THE OBJECTIVES OF THE THESIS

2.1. BOUNDARIES OF THE RESEARCH FIELD

Regarding the setting of a specific framework, the optimal versions among those presented were considered. Thus, the typology of the method proposed for development falls into the category of methods with **individual and potential comparative applicability** (method that can be applied to a single concept and comparatively by selecting the optimal concept, also having the option to be used both in the pre-production phase and in the post-production stage), the type of assessment process is **general-sensory** (involving both assessment by actual testing of the product and analysis of other visual, auditory, olfactory or gustatory elements if it is a relevant factor according to the type of product considered), data used are of the nature of **combined data** (it is intended to integrate both data related to predefined standards and uncertain data associated with preferential attributes or other similar elements, but addressed in relation to the specificity of the user or context of use, with the purpose to increase objectivity) and the type of criteria as described above it is specific to **hybrid methods** (all relevant elements related to features, dimensions and attributes will be integrated, taking into account the user typology and the corresponding reporting of the product to the related elements). Considering the degree of complexity that is desired to be obtained, it is indicated that the implementation of the method and the assessment itself is to be performed by **experienced evaluators**.

2.1.1. Establishing the assessment parameters

In establishing the assessment parameters, it was considered both the integration of all identified impact elements in the product design and the assessment approach from a new perspective in which the **features are analysed simultaneously for each dimension**, as they may distinctly affect the final form of the product depending on the perspective from which they are analysed. Considering the previous studies and the variations of the approached criteria, it was established the elements on the basis of which the assessment will be performed. Thus, in determining the assessment criteria, the features **colour** (including tone, saturation and brightness), **form** (including contour as shape and three-dimensional form), **material** (including texture and surface) and **dimensioning** (including linear dimensions and weight) were taken into account. The assessment will be based on the **technical, ergonomic, symbolism and aesthetic** dimensions for each feature, along with the **functional** dimension in which the factors arising from the total or partial combination of design elements will be considered and may impact the functionality of the product and implicitly the actual user experience.

2.1.2. Quality and design assessment

In this thesis, quality is not considered as a criterion for the assessment method, as it can impact multiple aspects both in terms of product and user experience, quality being considered consistently throughout the assessment and ultimately associated with a product defined by superior design. In order to understand how the concepts of design and quality intertwine in the product design assessment, the relationship between them was particularly addressed. In the paper 'A review on quality from the perspective of industrial product design assessment' [Paper 6], the **author proposed** an approach that starts from analysing in turn the relationships between the four components considered in the study, quality, product, design and user. The elements of the resulting concepts were structured based on the assessment dimensions described above, resulting the following aspects associated with quality: Functional dimension - which considers reliability and durability, maintenance and ease of repair, ease of use, consistency and compatibility (by reporting to the user), error prevention and originality along with creativity and innovation; Technical dimension - in which compliance with technical standards is considered; Ergonomic dimension - being considered the conformity in relation to anthropometric quantities and user safety as well as sensory conformity; Symbolism dimension - in which compliance with user meaning associations is addressed as specific cultural references; Aesthetic dimension - for which the perceived quality of the product through visual harmony and the quality of surface finishes are considered along with compliance with the context of use and perception of attractiveness. Based on the described analysis, the interdependence of design and quality concepts associated with the product can be deduced, which would therefore imply the possibility of integrating quality-associated components (previously identified) in the product design assessment, quality being considered constantly throughout the assessment both from the perspective of product functionality and also user experience.

2.1.3. Conclusions and presentation of assessment criteria

Considering the notions presented above, the assessment criteria were thus generated by the intersection of the product features on the vertical axis and the assessment dimensions on the horizontal axis, as presented in Table 2.1.

Table 2.1. Generated criteria corresponding to the proposed assessment method

<table>
<tr><th></th><th>Functional</th><th>Technical</th><th>Ergonomic</th><th>Symbolistic</th><th>Aesthetics</th></tr>
<tr><td>Colour</td><td rowspan="4">Functionality</td><td>Technical conformity of colour</td><td>Colour adaptation to the environment</td><td>Colour conformity to the target segment</td><td>Chromatic harmony</td></tr>
<tr><td>Form</td><td>Form adaptation to purpose</td><td>Form adaptation to the user's form</td><td>Form conformity to the target segment</td><td>Balance</td></tr>
<tr><td>Material</td><td>Material durability</td><td>The degree of comfort associated with the material</td><td>Material conformity to the target segment</td><td>Sensorial harmony</td></tr>
<tr><td>Dimensioning</td><td>Safe use</td><td>Dimensioning adaptation to the user's dimensions</td><td>Dimensioning conformity to the target segment</td><td>Proportionality</td></tr>
</table>

For each newly generated element (out of the 17 results) the **author proposed** two versions of the method, a standard version in which the criteria become absolute antagonistic attributes (having an absolutely positive character in fulfilling the criterion) and an extended version where the presented criteria are approached on the basis of additional studies, being considered in detail all aspects that may influence the criterion grading and implicitly the design of the product considered.

2.2 OBJECTIVES OF THE DOCTORAL THESIS

The general objective of the thesis represents the development of a holistic methodology of industrial design assessment that encompasses all the perspectives that can influence the design of the product and consequently the quality of both the product itself and the user experience. Considering the specificity of the proposed approach, the following associated objectives have been set:

- ***Theoretical objectives***

O.1. Identifying the parameters of the superior assessment methods, together with the disadvantages associated with them, the aim being to generate a structure for the general design assessment as objective as possible.

O.2. Identifying the set of all relevant elements related to the industrial product design, necessary step in establishing the assessment criteria.

O.3 Development of a framework for the differentiated application of the assessment according to the typology and the related class of the considered product.

O.4. Development of a perspective for interpreting the design elements, based on which the uncertain data associated with the user's specifics will be delimited as objectively as possible.

O.5. Generating an assessment format in the standard structure, in which the assessment can be performed based on specific antagonistic attributes established for each considered criterion.

O.6. Generating an assessment format in the extended version, situation in which the assessment will be able to be performed for each criterion based on additional studies, considering all the factors that can influence the interpretation of the criterion in question.

O.7. Presentation of the analysis perspectives for each considered criterion according to the additional studies and the development of sub-methods in their assessment in the situation where they are necessary in the grading of the method in the extended version.

O.8. Development of a relevant analysis structure following the grading of the criteria (along with the presentation of the application stages of the method), considering the possibility that, for a specific criterion, it will not be possible to assess according to the product typology, it is therefore necessary to propose a separate approach that does not impact the comparative assessment of product features.

O.9. Development of an analysis approach for the data resulting from the application of the assessment, based on which it can be interpreted (considering the relevant indicators) both individual and comparative assessments of products, along with the presentation of product improvement prospects based on assessment data.

- ***Practical objectives***

O.10. Carrying out an analysis study of the application of the proposed method on a series of industrial products, either in the pre-production stage and selecting the optimal concept or post-production and reporting the assessment indicators to the commercial success of the products.

O.11. Implementation of the method in a software program that significantly reduces the time required for application. Starting from the class selection and grading criteria, the calculation of the assessment indices and the interpretation of the data should be done automatically.

CHAPTER 3.

THEORETICAL CONTRIBUTIONS IN THE DESIGN ASSESSMENT OF INDUSTRIAL PRODUCTS

The proposed method for development ‘FTESE Assessment’ represents a general assessment method of industrial products design. The name of the method derives from the five dimensions considered as assessment framework on the basis of which the product features are addressed, named **functionality, technical, ergonomic, symbolism** and **aesthetic**. As the method is meant to be applicable to all categories of industrial products and the specificity and intended use of the product may differ, it has been found necessary to differentiate the importance of the dimensions according to the type of product. Thus, different approaches are needed for different product types, as certain dimensions may be more relevant than other dimensions in the assessment for a particular type of product selected, for example, aesthetic assessment is considered to be more important for decorative articles compared to other products such as machines (for which more importance is given to the technical dimension). Using the Locarno classification [180] based on the 32 classes of industrial products, the **author proposed** in the paper 'Strategic outlook in industrial design assessment based on product category' [Paper 4] a manner of establishing the dimension importance correspondent for each class. Thus, it was proposed to create a format for structuring the importance of the mentioned dimensions, associating the corresponding classes for each associated variation. As the functional dimension is related to the actual testing and involves the user experience itself (as presented in the previous chapter), the maximum importance for functionality has been established, regardless of the class considered. Thus, in the general structuring of the dimensions there were 24 organizational variations, the functional dimension being the main one, and for the other dimensions associations were made one by one, until the variation corresponding to the considered class is obtained. Although the importance of the size may vary for the 32 classes, all dimensions are considered in the assessment regardless of the product type, their presentation according to the type of class can be found in Table 3.40. from Subchapter 3.3. - 'Assessment Interpretation'.

3.1. PRE-ASSESSMENT STUDY

As described previously, certain criteria can be assessed only on the basis of product typology and user specificity as the associated attributes could be considered positive or negative depending on the given situation and as the dimensioning of a product can only be considered appropriate depending on the specifics of the user for whom the product is intended by referencing the associated anthropometric dimensions. In order to establish the framework parameters of the assessment on the basis of which the attributes will be delimited, the **author proposed** the introduction of the pre-assessment phase, in which obtaining the analysis data associated with the products will be done by completing the following steps:

- Identification of the product category - starting from the destination of use, the product typology will be established and the corresponding class will be identified among the 32 Locarno classes [180], according to Table 3.40. (found at the beginning of the application stages).
- Identification of the market segment - the market segment will be delimited according to the specifics of the users to whom the considered product is dedicated and the demographic details, the implications of the sociocultural context or other relevant data in the assessment will be noted.
- Identification of product specifications – in this category, there will be recorded as many data from the product features as possible, including colour scheme, typology of formal elements, associated materials and dimensioning elements both linear and weight related. Moreover, in the category of specifications will be noted also elements related to efficiency, these being necessary in the functional assessment.
- Analysis of the context of use - to obtain an overview of the context of the product, it is recommended to conduct a historical-competitive study to understand the evolution of the product over time (including the technological evolution of its components if necessary) and the context of use (also called ambient in the thesis), thus identifying elements related to the coherent integration of the product in both the physical and stylistic context. Also, the historical analysis takes into account the aspects related to product differentiation such as originality, creativity and novelty, elements associated with corporate identity and other relevant and necessary competitive aspects needed in assessing product performance (including the reporting of the efficiency of similar products from its category).

The data thus identified in the pre-assessment analysis together with the product presentation images and the brief description of the intended use are recorded in the 'Product Sheet', its format being distinct for individual assessment from comparative assessment (situation in which products are assessed on the same framework structure, products having the same intended use, considered segment, context and of course the same specific class, as it is recommended to perform the comparative assessment only for products of the same class and specific use). Considering the data identified in the pre-assessment analysis, in order to determine how the product features are influenced by the typology of the market segment and the context of use, in the paper ‘Correlation between market segmentation, industrial product features and context in design assessment’ [Paper 7] the **author proposed** to establish the degree of interdependence of the elements related to the three considered sections:

A. Market segment (A_1 - Age, A_2 - Gender, A_3 – Education, A_4 - Income, A_5 - Culture);
B. Product features (B_1 - Colour, B_2 - Form, B_3 - Material, B_4 - Dimension);
C. Context (C1 - History, C2 - Environment).

The relevant information interpreted from the study was structured and represented in the ‘Correlation Matrix’ presented in Fig. 3.1., in the graphic and numerical version. The degree of interdependence between the elements was graded using the descending scale ’●‘, ’◍‘, ’○‘, and ’x‘ in the situation in which it was not possible to associate a correlation between relevant elements.

	A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4	C_1	C_2
A_1		x	○	○	○	◍	◍	○	●	●	●
A_2	x		○	◍	○	●	●	○	◍	○	◍
A_3	○	○		●	◍	◍	○	◍	○	◍	○
A_4	○	◍	●		◍	○	○	◍	○	○	○
A_5	○	○	◍	◍		●	◍	●	○	●	●
B_1	◍	●	◍	○	●		○	●	○	◍	●
B_2	◍	●	○	○	◍	○		◍	○	◍	○
B_3	○	○	◍	◍	●	●	◍		◍	●	◍
B_4	●	◍	○	○	○	○	○	◍		○	◍
C_1	●	○	◍	○	●	◍	◍	●	○		◍
C_2	●	◍	○	○	●	●	○	◍	◍	◍	

x - 0
○ - 1
◍ - 2
● - 3

	A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4	C_1	C_2
A_1		0	1	1	1	2	2	1	3	3	3
A_2	0		1	2	1	3	3	1	2	1	2
A_3	1	1		3	2	2	1	2	1	2	1
A_4	1	2	3		2	1	1	2	1	1	1
A_5	1	1	2	2		3	2	3	1	3	3
B_1	2	3	2	1	3		1	3	1	2	3
B_2	2	3	1	1	2	1		2	1	2	1
B_3	1	1	2	2	3	3	2		2	3	2
B_4	3	2	1	1	1	1	1	2		1	2
C_1	3	1	2	1	3	2	2	3	1		2
C_2	3	2	1	1	3	3	1	2	2	2	

Fig. 3.1. Correlation matrix of the three considered sections - market segment, product characteristics and context, author's proposal [Paper 7]

As presented, the organization is based on the associated rank, all relationships being relevant and can have an impact on the final form of the product, even with minimal impact being notable the existence of a relationship. Thus, when the product is analysed from the perspective of a particular feature, it is important to take into account its specificity in relation to the associated elements, the order being given by the rank of influence.

3.2. PRODUCT ANALYSIS BASED ON ASSESSMENT DIMENSIONS AND CRITERIA GRADING

Depending on the desired degree of analysis depth, in order to generate the assessment structure, the **author proposed** the following approach, with the two corresponding versions:

I. Standard version of the FTESE method

In the standard version, the assessment criteria are generated by antagonistic attributes specific to the considered dimension, these being presented in column I of Table 3.3., together with the specific correspondent for each dimension, respectively feature.

II. Extended version of the FTESE method

Based on the same analysis structure, the extended version of the method involves further in-depth studies for each considered criterion. The corresponding assessment dimensions in the extended version are presented in column II of Table 3.3., their extended version and additional explanations being developed separately in the following subchapters (from 3.2.1. to 3.2.5.), together with the associated sub-methods.

Table 3.3. The assessment structure of the FTESE method in the standard version, alongside with the associated additional studies in the extended version, proposed by the author

Dimension	**I. Antagonistic attributes in the standard version**		**II. Additional studies**
FUNCTIONAL	Non-functional	Functional	3.2.1.
TECHNICAL			
Colour	Not in accordance with technical standards	In accordance with technical standards	3.2.2.1.
Form	Unsuitable to purpose	Suitable to purpose	3.2.2.2.
Material	Precarious	Durable	3.2.2.3.
Dimensioning	Does not ensure safe use	Ensures safe use	3.2.2.4.
ERGONOMICS			
Colour	Not adapted to the environment	Adapted to the environment	3.2.3.1.
Form	Not adapted to the user's form	Adapted to the user's form	3.2.3.2.
Material	Does not provide comfort	Provides comfort	3.2.3.3.
Dimensioning	Not adapted to the user's dimensions	Adapted to the user's dimensions	3.2.3.4.
SYMBOLISM			
Colour	Noncompliant with the target segment	Compliant with the target segment	3.2.4.1.
Form	Noncompliant with the target segment	Compliant with the target segment	3.2.4.2.
Material	Noncompliant with the target segment	Compliant with the target segment	3.2.4.3.
Dimensioning	Noncompliant with the target segment	Compliant with the target segment	3.2.4.4.
AESTHETICS			
Colour	Nonharmonious	Harmonious	3.2.5.1.
Form	Unbalanced	Balanced	3.2.5.2.
Material	Unpleasant to the touch	Pleasant to the touch	3.2.5.3.
Dimensioning	Disproportionate	Proportionate	3.2.5.4.

For both proposed versions, the scoring of the criteria will be done on the same principle, the ideal value for the final design assessment index of industrial products being 100 and the maximum value for one dimension being 20 (for all five proposed dimensions). For dimensions with associated features, the criteria will be noted on the basis of a 5-step Likert scale (total disagreement, disagreement, neutral, agreement and total agreement) with values from 1 to 5, according to the maximum total of 20 associated with the dimension. Thus, for the functional dimension (analysis in direct relation to the user experience, further developed and presented in subchapter 3.2.1.), using the same five-step scale, the associated values are 4, 8, 12, 16 and 20 for maximum value as it is for the other dimensions, but it also implies in the standard version the granting of a much higher weight for functionality (considered as an attribute) compared to the other attributes such as harmony or balance.

3.2.1. Functional assessment

3.2.1.1. Analysis of the functional assessment structure

The functional analysis will determine the extent to which the product is adapted to the purpose of use, taking into account the current and in time experience of use of the product. Considering a parallel between the 'human needs' proposed by Maslow [94] and the 'product needs', in the effective notation of the criterion in the extended version of the method, the **author proposed** the analysis of the elements associated with the assessment by direct, indirect, relational, connection and auxiliary reporting, on the basis of the three levels of reporting to the product (macro-assembly, assembly and micro-assembly) as presented in Table 3.4., in which, after noting the proposed criteria, the index E_F representative for functional assessment, will be determined.

Direct assessment is defined by reporting to the functional capacity of the product, being represented by performance based on the relation to competing products, efficiency as the capacity of the product to fulfil its function and the third component the degree of finishing. Finishing is approached as functionality associated with the consistency of the details (reflected by the precision of assembly and finishes), along with the functional honesty considered from the perspective of the reproductions of the elements, the finish is often translated by the confidence level given to the product. Considering the criteria associated with direct functionality, product selection is most often made on the basis of these functional aspects. It should be noted that reliability, innovation and quality, both in the functional assessment and in the general assessment are not considered attributes and are not addressed as simple criteria. The concepts described are integrated in the method, as presented in the analysis of the quality approach (subchapter 2.1.2.), however innovation, reliability and quality are specific to a product defined by superior design in general and are associated with the result of the proper implementation of the design elements. Indirect assessment is considered from the perspective of reporting functionality to ease of use. In macro-assembly, the physical compactness is taken into account along with the ease of positioning and storage (the ability of the product to be foldable or stackable is also important, notable features especially in the case of products that are stored mainly with products from the same category), compactness being also relevant in facilitating the development of activities in the vicinity of the product. In terms of intuitiveness, this is reflected in the product's ability to be easily understood functionally, and in the assessment, it is analysed along with ease of use and its implications [75, 128]. Thus, intuitiveness is represented by the degree of communication between product and user, being all the more relevant for products with complex functions, in which case, the way of accessing secondary functions must be presented in a comprehensible manner so that the product is as easy to understand as possible. Repairability is defined by the ability of the product to be repaired along with the possibility of replacing components [139], being considered along with ease of maintenance and cleaning (relevant aspect in prolonged use, which may be influenced by the physical compactness of the product).

Along with the direct and indirect assessment of functionality, the author proposed to consider the segments of relational, connection and auxiliary functionality assessment. These are associated with the degree of trust placed in the product and cannot be approached from the strict perspective of a feature, also having an impact on the relationship between the product and the user. The relational assessment analyses the degree of adaptation of the product to the context through compatibility, adaptation to related products through adaptability and to auxiliary products through flexibility. As an example, in the case of a printer, the product must be in a compatibility relationship with the room or assembly in which it will be stored and used (in which case dimensioning has a major impact, the other product features being also relevant), adaptability to connected (related) products such as computers, external memory devices, phones or other forms of data transfer used with preponderance and flexibility over paper type, cartridge type etc. or other specific auxiliary products required for fulfilling the function. The related assessment of functionality starts from sustainability, which is highlighted by the environmental impact and socio-economic considerations [60, 157], thus being relevant the long-term and very long-term influence of the product. Along with sustainability, the concept of product validity is proposed, taking into account the degree of utility and the real contribution that the product brings to the user, starting from the premise that a product must primarily serve a purpose and the design is meant to meet real needs [109]. Regarding creativity, in this case it is not given relevance to the creativity of the design process (even if a creative process can result in a creative product, this is part of the design stage), being relevant in this case the creativity associated with the result that takes into account the novelty and feasibility elements of the concept [162]. The novelty in this case is seen from the perspective of the originality of the concept and not the formal details (evaluated in the auxiliary assessment by the relation familiarity - novelty), being also important to understand how creativity is associated with the product, the presence of ornamental details or a strong playfulness character of the product form is not an indicator of creativity in industrial products and cannot be associated as indicators of complexity, as creativity can be a very simple solution to a complex problem associated with the product. Thus, certain important aspects related to the degree of product innovation can be attributed to the connection assessment [78, 133], although innovation is not represented fully in the connection assessment, being also necessary to associate a high value for the general assessment indicator (as presented above). The auxiliary assessment starts from the analysis of the relation of familiarity - novelty and formal honesty - playfulness, concepts further developed as sub-methods in subchapters 3.2.1.2., respectively 3.2.1.3. Regarding the third subcategory, as seen in Figs. 3.2., for any considered system, its style will take into account the harmonious adaptation to the macro-ensemble, thus proposing the concept of stylistic coherence, for which the coherence of the message transmitted by the product style will be evaluated by referring to the degree of harmony of its details (being considered both the general shape, colour scheme, materials, decorative elements, even the font or shape of the control operators).

Stylistic coherence can be all the more important as, even in the relationship between the formal representation of the product and its function, the unity of the message transmitted must be considered [51].

Fig. 3.2. Representation of the stylistic adaptation relationship

Considering the pyramidal structure, the five proposed sections impact the functionality of the product differently. Thus, as presented in Table 3.4, the sections were organized according to the degree of importance, the direct assessment having the highest importance of 30%, and the auxiliary one the lowest, of 10%. The product-specific functional assessment format will be completed by grading each criterion (out of the fifteen proposed) on a scale of 1 to 5 in relation to the extent to which the product fulfils its function, 1 for minimum value and 5 for maximum value. Considering the maximum value of a criterion, the maximum value associated with a reporting type is deduced as F_{max} of 15, representative for the maximum value of three corresponding criteria, F_{max} being necessary in the determination of the functional assessment indicator E_F.

Table 3.4. Functional assessment format, proposed by the author

Relation type	**Relation level**	**Criterion**	**Indicator**
Direct p_{Ed} = 30%	Macro-ensemble	**Performance** (product's degree of efficiency compared to the current products in its category)	Fd_1 =
	Ensemble	**Efficiency** (the product's ability to perform its function, along with ease of use)	Fd_2 =
	Micro-ensemble	**Finishing** (finishes' precision together with the elements' functional honesty)	Fd_3 =
Indirect p_{Ei} = 25%	Macro-ensemble	**Physical compactness** (along with ease of positioning and storage)	Fi_1 =
	Ensemble	**Intuitivity** (along with ease of use)	Fi_2 =
	Micro-ensemble	**Repairability** (along with ease of maintenance and cleaning)	Fi_3 =
Relational p_{Er} = 20%	Macro-ensemble	**Compatibility** (degree of adaptation to context **-** environment)	Fr_1 =
	Ensemble	**Adaptability** (degree of adaptation to related products)	Fr_2 =
	Micro-ensemble	**Flexibility** (degree of adaptation to auxiliary products)	Fr_3 =
Connex p_{Ec} = 15%	Macro-ensemble	**Sustainability** (environmental impact and ability to be recycled along with socioeconomic impact)	Fc_1 =
	Ensemble	**Validity** (degree of utility and contribution)	Fc_2 =
	Micro-ensemble	**Creativity** (along with the concept's originality)	Fc_3 =
Auxiliary p_{Ea} = 10%	Macro-ensemble	**Familiarity - Novelty** (approached from the perspective of the relation's neutrality)	Fa_1 =
	Ensemble	**Formal honesty – Playfulness** (the extent to which formal honesty is affected by playfulness)	Fa_2 =
	Micro-ensemble	**Stylistic coherence** (considering the degree of stylistic harmony of the product details)	Fa_3 =

Following the notation of the functional evaluation criteria, the value of the functional evaluation index E_F is determined based on the relation (3.9), by summing up the specific terms generated by a certain type of relation, considering for them the corresponding weighted value and the maximum associated value. By replacing the weights values p_E and the maximum value of a relation F_{max}, E_F can also be expressed in the form presented in the relation (3.10).

$$E_F = p_{Ed} * \frac{\sum_{j=1}^{w} Fd_j}{F_{max}} + p_{Ei} * \frac{\sum_{j=1}^{w} Fi_j}{F_{max}} + p_{Er} * \frac{\sum_{j=1}^{w} Fr_j}{F_{max}} + p_{Ec} * \frac{\sum_{j=1}^{w} Fc_j}{F_{max}} + p_{Ea} * \frac{\sum_{j=1}^{w} Fa_j}{F_{max}} \quad (3.9)$$

$$E_F = \frac{30 * \sum_{j=1}^{w} Fd_j + 25 * \sum_{j=1}^{w} Fi_j + 20 * \sum_{j=1}^{w} Fr_j + 15 * \sum_{j=1}^{w} Fc_j + 10 * \sum_{j=1}^{w} Fa_j}{15} \quad (3.10)$$

where, E_F represents the functional assessment indicator, p_E represents the specific importance of a type of relation, F_{max} represents the maximum value of a relation type, Fd_j is specific to direct reporting, Fi_j is specific to indirect reporting, Fr_j is specific to relational reporting, Fc_j is specific to connection reporting, Fa_j is specific to auxiliary reporting, j is an indicator specific to a type of relation and w represents the number of elements of a category.

Table 3.5. Reporting structure of functionality to the general assessment, proposed by the author

Reference interval E_F	Associated value in general assessment C_F	Likert correspondent in general assessment
$E_F \in [20, 36]$	4	Total Disagreement
$E_F \in (36, 52]$	8	Disagreement
$E_F \in (52, 68]$	12	Neutral
$E_F \in (68, 84]$	16	Agreement
$E_F \in (84, 100]$	20	Total agreement

The **author proposed** the notation of the functional dimension on the basis of Table 3.5., in which it is presented the correspondence of the values obtained for the functional assessment index E_F to the corresponding values from the general assessment C_F.

3.2.1.2. Auxiliary analysis of the relation familiarity - novelty

Starting from the premise of A. Dumitrescu [39] to balance the relation of familiarity - novelty, an aspect that requires special attention in the functional-auxiliary assessment stage is the analysis of the elements that could influence the relation. Considering the product in relation to familiarity versus novelty, it can be seen that both attributes can be associated with positive and also negative aspects and have a general character not only influenced by product typology, as novelty elements generate interest, can contribute to innovation and implicitly to the competitive advantage but at the same time they need to be balanced by familiarity so that a product reflects the purpose of use and the associated significance, to be intuitive and easy to use and last but not least to generate the feeling of trust. Thus, the **author proposed** the following way of analysing the relation between familiarity and novelty, by assigning the character of neutrality, in which the features will be noted in turn based on the seven proposed steps starting from -3 for high degree of familiarity and up to 3 for high degree of novelty. Since the aspects related to the features can be considered both familiar and defined by novelty (in the given context), in analysing the product, the features will be graded both in F and N sections, and in the absence of the considered elements, the neutrality of the section will be noted in the central column.

Table 3.6. The analysis structure of the familiarity - novelty relation, proposed by the author

	F - Familiarity			Neutral	N - Novelty			
	F_3	F_2	F_1		N_1	N_2	N_3	
	High	Medium	Low	Absent	High	Medium	Low	
	-3	-2	-1	0	1	2	3	
Colour								FN_c=
Form								FN_f=
Material								FN_m=
Dimensioning								FN_d=
Total	TF_3 =	TF_2 =	TF_1 =	0	TN_1 =	TN_2 =	TN_3 =	
T_{FN} =	F_P =				N_P =			

According to Table 3.6., TF_i and TN_i indicators will be determined by summing up the values from the corresponding columns and based on them the total values for the familiarity and novelty indices will be calculated according to the relation (3.11), respectively (3.12). Although they are independent of the indicator associated with the familiarity - novelty ratio, given the specificity of the study, it was also considered relevant to determine the neutrality values for the features, these being calculated using the relation (3.13).

$$F_P = TF_3 + TF_2 + TF_1 \tag{3.11}$$

$$N_P = TN_1 + TN_2 + TN_3 \tag{3.12}$$

$$FN_k = F_k + N_k \tag{3.13}$$

where, F_P represents the total value of familiarity, N_P represents the total value of novelty and FN_k is the associated value of a k feature from the considered four.

Since the ideality associated with the report would imply the maximum value for both familiarity and novelty, for the values F_P and N_P the distance to their maximum value was set and the total value of the ratio T_{FN} was determined as the mean of the two variations, as presented in relation (3.14).

$$T_{FN} = \frac{(|FN_{max}|-|F_P|) + (|FN_{max}|-|N_P|)}{2}, \quad |FN_{max}| = 12 \tag{3.14}$$

where, T_{FN} represents the total value associated with the familiarity - novelty ratio and FN_{max} is the maximum value for sections F and N.

Table 3.7. Structure of reporting T_{FN} to the general assessment, proposed by the author

Value of T_{FN}	**Associated value in functional assessment**
$T_{FN} \geq 11$	$Fa_1 = 1$
$T_{FN} \in [8, 11)$	$Fa_1 = 2$
$T_{FN} \in [5, 8)$	$Fa_1 = 3$
$T_{FN} \in [2, 5)$	$Fa_1 = 4$
$T_{FN} \in [0, 2)$	$Fa_1 = 5$

The **author proposed** the notation of the criteria based on the established correspondence in Table 3.7., by reporting the obtained values for T_{FN} to the segment of auxiliary elements in the functional assessment.

3.2.1.3. Auxiliary analysis of the relation formal honesty - playfulness

The concept of product honesty, often encountered in the form of 'honest design' [32], refers to the extent to which the product can do what it promises, the principle can be applied formally as well as through the associated significance. Lack of honesty along with the non-original repetition of a style generates the presence of kitsch and clichés [12] which would greatly affect the degree of trust given to the product. In terms of playfulness, this can be approached both from the perspective of interaction with the product [73] and from a visual perspective through shapes and colours [67]. Visually, the playful character implies the adaptation on a product of some already existing recognized concepts, these being most of the time elements from nature or other established concepts. Assuming a far too strong visual playful character and the strong reproduction of an already existing concept with a certain destination on a product defined by a completely different destination directly impacts formal honesty. Thus, in order to establish a necessary delimitation framework in the situation where the playful character can affect the formal honesty, the **author proposed** the approach presented in Table 3.8. Within it, the chromatic discordance is considered together with the degree of reproduction of the form for both the general form and secondary forms encountered in the product details.

Table 3.8. Grading structure of the formal honesty - playfulness relation, proposed by the author

Degree of form replication	General form	Decorative elements	Chromatic scheme	Degree of chromatic discordance
	p_{Fg} = 9	p_{Ed} = 3	p_{Sc} = 1	
Very strong	5	5	5	Very strong
Strong	4	4	4	Strong
Moderate	3	3	3	Moderate
Weak	2	2	2	Weak
Absence of replication	1	1	1	Absence of discordance
	$i_{Fg} =$	$i_{Ed} =$	$i_{Sc} =$	$OL =$

Based on Table 3.8. the three proposed categories will be noted on a scale from 1 to 5, considering the degree of form replication (for the general form and the decorative elements) and the degree of chromatic discordance, the values for the indicators i_{Fg}, i_{Ed} and i_{Sc} being obtained, based on which it will be determined the value for OL using the relation (3.15), by summing the values of the indicators reported to the corresponding weights.

$$OL = p_{Fg} * i_{Fg} + p_{Ed} * i_{Ed} + p_{Sc} * i_{Sc} \tag{3.15}$$

where, OL is the indicator for the formal honesty – playfulness relation, p_{Fg} is the ratio of the general form, p_{Ed} is the ratio of the decorative elements, p_{Sc} is the ratio of the colour scheme, i_{Fg} is the value associated to the general form, i_{Ed} is the value associated to the decorative elements and i_{Sc} is the value associated with the colour scheme.

Table 3.9. Reporting structure of OL values to the functional assessment, proposed by the author

Value of OL	Associated value in functional assessment
$OL \geq 45$	$Fa_2 = 1$
$OL \in [40, 45)$	$Fa_2 = 2$
$OL \in [35, 40)$	$Fa_2 = 3$
$OL \in [30, 35)$	$Fa_2 = 4$
$OL < 30$	$Fa_2 = 5$

For all product classes considered, except Class 21, the author proposed the actual grading of the criterion based on Table 3.9. by reporting the obtained OL values to its correspondent from the functional assessment. When referring to the formal honesty – playfulness relation, an exception in assessment is represented by 'Games, toys, tents and sports goods' (as seen in Table 3.40.), for this being recommended to approach playfulness from the tangible and not formal perspective, situation in which, the notation of the criterion will be done based on Table 3.10. recording the level of interactivity.

Table 3.10. Grading structure of ludic character from functional perspective (interactivity), proposed by the author

The level of interactivity of the product	Associated value in functional assessment
The product is not interactive	$Fa_2 = 1$
The product has a low degree of interactivity	$Fa_2 = 2$
The product has an average degree of interactivity	$Fa_2 = 3$
The product has a high degree of interactivity	$Fa_2 = 4$
The product has a very high degree of interactivity	$Fa_2 = 5$

3.2.2. Technical assessment

3.2.2.1. Colour assessment from technical perspective

The technical assessment will analyse the extent to which the colour scheme favours the use of the product, thus, the **author proposed** to evaluate the colour based on two categories. For category A, the conformity to purpose of the surfaces colours is considered by analysing the extent to which the colour (along with the associated aspects, brightness, saturation etc.) favours the desired technical effect. For example, colour may affect the maintenance of the product or the degree of heat absorbed by its surface, as light shades reflect light and absorb less heat, while dark shades absorb light, for the effect thus generated by the colour scheme, the correspondence being noted in relation to the specifics of the product. Thus, the analysis of category A will be performed based on Table 3.11., establishing the extent to which the colour scheme is favourable or not to the product from a technical point of view.

Table 3.11. Grading structure of the specificity of the colour scheme in relation to the degree of conformity to purpose, proposed by the author

The specificity of the colour scheme in relation to the degree of conformity to purpose	**Value of t_A indicator**
The colour scheme strongly disadvantages the product	1
The colour scheme relatively disadvantages the product	2
The colour scheme does not disadvantage or favour the product	3
The colour scheme relatively favours the product	4
The colour scheme strongly favours the product	5

With regard to category B, colour is approached in the light of the generally accepted conventions on colour schemes and their associated meanings, in the technical analysis of the product (for the second category), the interpretation of colour coding can be performed only within a conventional system. The colours thus chosen are specific to certain dominant features in order to be distinguished from those in the same category. Technical colour systems are a form of communication between the product and the user, with the aim of facilitating the use of the product, which is all the more important as an improper form of coding can affect safety in use. Depending on the positioning of the technical elements, the **author proposed** three specific situations in which colour coding systems are found:

a) Colour systems integrated in the product (components) - an eloquent example of a system integrated in the product that presents colour coding is the set of electrical cables in the structure of electronics. Regarding the standardization of colour codes of electrical cables, the international standard currently used is IEC 60445:2017 “Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors” [171] which contains information on the identification and differentiation of electrical cables, being found a correlation between the function of the cable and the related colour (for example the phase is represented by the brown cable, grounding is represented by the yellow-green bicolour cable etc.).

b) Colour systems integrated into the external details of the product (interface) - In the actual use of a product there are a number of elements (often encountered in the form of contact operators) symbolically represented in certain colour schemes.

▪ Red - general symbol for the 'off' function. In the absence of a specific 'button' for communicating the start function (in the case of certain products there are separate commands for communicating the on or off operating status), the red button generally associated with the stop function is one of the most used, for that it should be as visible as possible and positioning should also be a priority;

▪ Green - in some cases, there is only one control operator with separate additional LEDs, as a result, the main button that indicates the status of the activity is colourless and will be accompanied by red or green depending on the status of the product, in this case, green being representative for the 'on / active' function;

▪ Orange - sometimes encountered in the form of yellow, orange symbols are associated with the warning function, need for maintenance or an ongoing action, which are usually accompanied by a flashing light signal;

▪ White - white signals are mainly used to report the activity status of the product. Continuous white light signals the active status when the product is at long-term rest and ready for use and the flashing white light signals the process or the cessation of activity (when the light signal disappears shortly after the intermittent signal);

▪ Blue - the purpose of using the blue colour is similar to white, the difference is given by the importance of signalling the status of activity. White operators have a higher degree of subtlety, so the use of the colour blue is recommended if the signalling of the activity of the product has a slightly higher importance compared to another product signalled through the white colour.

The use of certain basic colour symbols, generally accepted, to distinguish the functions, is to support the ease of use, thus increasing the user's reaction speed by eliminating additional details of information. Graphic symbolic details are considered intuitive and can be interpreted in a wide cultural spectrum, unlike written information that is limited primarily by the language barrier.

c) Additional colour systems - Additional technical details can be found in the form of coloured symbols on the surface of the products. Additional systems are strictly dependent on the use of graphic symbols to inform the purpose, for example, red warning signals are accompanied by an exclamation mark. Associated with these colour systems is standard ISO 7010:2019 ”Graphical symbols - Safety colours and safety signs” [174], standard which includes references to the colour codes used in the case of warning and safety symbols, the colours being indicated as red in the case of prohibition and warning signals in case of high danger, yellow in the case of warning and moderate danger signals that however require attention, green in the case of signals referring to safety (emergency - assistance in case of danger) and blue to signal the obligation. Considering the connection of the product with the user, it is important that all forms of communication of the product are compatible with each other, as the symbolism of the form or the written message must also associate the corresponding colour, for example the word stop must be presented next to red (as normally associated) and not green [66], otherwise the transmitted information tends to become conflicting, generating the Stroop effect, which reduces the reaction speed [92].

To the extent to which the product typology allows the evaluation of colour systems, the grading of category B based on Table 3.12. will be done by establishing the degree to which technical colour coding standards are met for all proposed situations taking into account both international and regional coding variations.

Table 3.12. Grading structure of colour systems in technical assessment, proposed by the author

The specificity of colour systems from a technical point of view	**Value of t_B indicator**
Colour systems affect the product's safety	1
Colour systems hinder the use the product	2
Colour systems do not facilitate or hinder the use of the product	3
Colour systems facilitate the use the product	4
Colour systems are in full conformance with the specificity of the product	5

When noting the criterion, the values assigned for the two considered categories will be recorded in Table 3.11. and Table 3.12., based on them, according to the relation (3.16) being determined the T_c indicator that is associated with the technical assessment. In the situation in which t_B cannot be evaluated according to the product typology, the criterion will be noted based on the value of the t_A indicator.

$$T_c = \frac{t_A + t_B}{2} \tag{3.16}$$

where, T_c represents the indicator for the technical assessment of colour, t_A is the value assigned for the conformity to purpose and t_B is the value assigned to the category of colour technical systems.

Table 3.13. Reporting structure of the technical colour criterion, proposed by the author

Associated value for T_c indicator	Associated value in general assessment C_{c1}	Likert correspondent in general assessment
$T_c = 1$	1	Total disagreement
$T_c \in (1, 2]$	2	Disagreement
$T_c \in (2, 3]$	3	Neutral
$T_c \in (3, 4]$	4	Agreement
$T_c \in (4, 5]$	5	Total agreement

Thus, the **author proposed** the assessment of the criterion based on the analysis of conformity to purpose of the colour scheme along with the specific situations of colour coding systems associated with the evaluated product, taking into account the extent to which colour coding facilitates information communication and product use. According to the established intervals, the notation of the criterion will be done based on Table 3.13. by reporting the value obtained for T_c to the associated value in the general assessment.

3.2.2.2. Form assessment from technical perspective

Considering the form from a technical perspective, both the geometry of the components and the associated structural relationships [93] and the general shape and its implications [63] can influence the technical superiority of a product from a formal point of view. Especially since form represents at least partially the solution to a functional problem [115], it is important to consider the suitability of the form for the purpose, taking into account the functional implications and experience of use. Thus, from the perspective of technical study of the form in assessment, the extent to which the general form is adapted to purpose and corresponding to the technical constraints is analysed, taking into account at the same time the way that form affects the safety in use. The extent to which the function determines the overall shape of the product is not analysed, however both the function of the product and the components will be taken into account in the form analysis.

Table 3.14. Grading structure of the technical form criterion, proposed by the author

The specificity of the form from a technical point of view	Associated value in general assessment C_{f1}	Likert correspondent in general assessment
The form is totally unsuitable for safety in use	1	Total disagreement
The form is mostly unsuitable for safety in use	2	Disagreement
The form is mostly adapted to purpose	3	Neutral
The form assures safety and is adapted to purpose	4	Agreement
The form is in full conformance with the product's purpose of use	5	Total agreement

The **author proposed** the notation of the criterion and the determination of the associated indicator in the general assessment based of Table 3.14., the values associated with the criteria being determined according to the correspondence of the product to the specifics of the form from a technical point of view.

3.2.2.3. Material assessment from technical perspective

From a technical point of view, the analysis of the material involves a complex study in which the mechanical, electrical, optical, magnetic, chemical and thermal properties are considered [126]. Selecting one material at the expense of another in product design is all the more difficult as technological evolution generates a wide range of materials defined by major differences associated with distinct properties, especially as new superior materials appear, generated from combining several ones into a final one defined by the benefits of the components materials or having new properties, as is the case with alloys or composites. Thus, due to the wide range of available materials, the properties associated with a series of certain materials will not be presented in the thesis, but it is recommended that, before analysing the criterion, an analysis of the component materials of the product should be performed, taking into account their properties [7, 16, 41, 59]. The analysis determines to what extent the materials are beneficial or not to the situation in question, as the superiority of a material is considered in relation to the purpose of use of the product, since technical superiority of a metal over a textile material cannot be associated without considering the typology and the context of use of the product. When the technical analysis of the material is performed, it is recommended to pay special attention to the following details: hardness (analysed from the perspective of deformation resistance and wear resistance, relevant especially from the perspective of long use of the product), elasticity-plasticity ratio (depending on the desired effect according to its intended use), electrical and thermal conductivity (in which the properties of the material are delimited from the technical perspective in relation to the ergonomic one, as conductivity may be a technical property required by the specifics of the product but may severely affect the user experience or even safety in use, in which case an additional component made of isolating material is required).

Table 3.15. Grading structure of the technical material criterion, proposed by the author

The specificity of the material from a technical point of view	Associated value in general assessment C_{m1}	Likert correspondent in general assessment
The material is totally unsuitable for the product's purpose of use	1	Total disagreement
The material is mostly unsuitable for the product's purpose of use	2	Disagreement
The material does not affect the product's purpose of use	3	Neutral
The material is mostly suitable for the product's purpose of use	4	Agreement
The material is in full conformance with the product's purpose of use	5	Total agreement

The **author proposed** the notation of the criterion according to Table 3.15. The technical assessment of the material will take into account all the materials of the product components and the extent to which the associated properties correspond to the purpose of use.

3.2.2.4. Dimensioning assessment from technical perspective

In the approach of technical dimensioning, the extent to which dimensioning affects the user experience is analysed, considering first of all the user's safety and the impact that sizing has on him. Improper sizing can affect product stability as well as performance and can even impact its life and thus its reliability.

In the case that the product typology requires it, in the analysis of the dimensioning from a technical point of view, the geometric constraints of the product will be considered by taking into account the reference standards associated with the product type. The establishment of the reporting elements will be done through the standards identified based on ISO 14638:2015 "Geometric Product Specifications (GPS) - Matrix model" [175] which includes the group of standards associated with geometric specifications, which are presented from the perspective of organization, characteristic relationships and purpose of use. Among the standards included in ISO 14638:2015 are those mainly used, such as ISO 8015:2011 [176], ISO 14405-1:2010 [177], along with ISO 14405-2:2011 [178]. The selection of one standard to the detriment of another will be made in relation to the type of product, taking into account the relevance of the standard approach to the specifics of the product considered.

The analysis of the criterion will consider both the formal assembly of the product (general dimensioning), the subassembly elements grouped by function (dimensioning of components) and the connecting parts (dimensioning of details) and will determine the degree to which their dimensioning impacts the capacity of the product to fulfil its purpose of use.

Table 3.16. Grading structure of the technical dimensioning criterion, proposed by the author

The specificity of dimensioning from a technical point of view	Associated value in general assessment C_{d1}	Likert correspondent in general assessment
Dimensioning is totally unsuitable for safety in use	1	Total disagreement
Dimensioning is mostly unsuitable for safety in use	2	Disagreement
Dimensioning is mostly adapted to purpose	3	Neutral
Dimensioning assures safety and is adapted to purpose	4	Agreement
Dimensioning is in full conformance with the product's purpose of use	5	Total agreement

The **author proposed** the notation of the criterion based on the specific reporting of the product dimensioning to the value associated in the general assessment according to Table 3.16. by analysing the specific situations, being considered the correspondence to purpose and the impact of the product dimensioning on safety in use.

3.2.3. Ergonomic assessment

3.2.3.1. Colour assessment from ergonomic perspective

Ergonomic colour assessment is performed by relating the colour scheme to the context of the product, taking into account the sensory associations and the psychological effect generated by its colour. Thus, unlike the assessment of significance in which colour preferences are taken into account according to the specifics of the user using market segmentation, in the case of ergonomics, colour analysis does not relate to personal affinity for a colour, as there is a considerable difference between personal preferences and favoured colours for certain objects [65], as there are variations in colour preference in relation to the specifics of the product [9, 127, 153]. It is also noticeable a preferential variation according to the product typology and in relation to the level of saturation or brightness, not just hue [76]. Analysing the perception of colour and the generated sensation, there are two specific elementary correlations, between the perceived distance of an object [8] and the perception of temperature [68] from the wavelength associated with a colour. Thus, the colours with longer wavelengths (red, orange, yellow) give the feeling of proximity and warmth, and those with shorter wavelengths (green, blue, purple) give the feeling of distance and coldness [38]. Also, considering the generated sensation, colour can influence not only the perception of temperature, but also of sound, taste or smell [155]. As mentioned, the perceived sensation and the nature of the specific association of a colour can also be influenced by variations in saturation and brightness, and a major influence is represented by the context of use, as the relationship between colour and context is stronger on colour depending on the frame in which it is perceived [66], the colour of the environment in turn influencing human behaviour [1]. There are also a number of external factors responsible for colour perception, which can be influenced by the contrast effect (e.g. tone contrast, complementary contrast or simultaneous contrast) [71] or brightness [66] as is the case with Purkinje phenomenon [150] as the way a colour is perceived is due to changes in light conditions.

Table 3.17. Grading structure of the ergonomic colour criterion, proposed by the author

Colour specificity from an ergonomic point of view	Associated value in general assessment C_{c2}	Likert correspondent in general assessment
The colour scheme is totally inappropriate for the context of use	1	Total disagreement
The colour scheme is mostly inappropriate for the context of use	2	Disagreement
The colour scheme does not affect the context of use	3	Neutral
The colour scheme corresponds to the context of use	4	Agreement
The colour scheme is in full accordance with the context of use	5	Total agreement

The **author proposed** the notation of the criterion, considering the analysis of the sensation generated by the chromatic scheme and the way it is related to the specifics of the use context according to the product typology, marking according to Table 3.17. the extent to which the two segments are correlated. Also, if it is applicable according to the product typology, an additional analysis to identify the favourable correlations between colours and the specific activity associated with the product is recommended, for example, both the environment and the furniture defined by warm colours favour analytical thinking [64]. It should be noted that, along with the influence on the psyche, colours can also have an influence on human physiology [38, 90], for example, the identified relationship between the green-blue colour of the context and the stimulation of heart rate [2]. Due to the complexity of the study, the impact of colour on human physiology is not the subject of this thesis, as large variations can be noticed for physiological effects or colour schemes, being also possible potential differences due to the duration of the exposure period.

3.2.3.2. Form assessment from ergonomic perspective

The ergonomic study of form is considered from the perspective of adapting the product form to the form of the human body, analysing how the form influences the user experience, as the form must ensure ergonomic efficiency [15], being relevant both the overall shape of the product and the shape of components if they influence the user experience, as is the case with products with handles, the handle having the role of facilitating the interaction between the product and the user [50]. In order to identify formal elements with which the user comes into contact in the use experience, the **author proposed** the following analysis in which the series of activities involved in the actual use of the product according to the purpose for which it was designed is considered, also called connex activities and additional secondary implications of use, called auxiliary activities, which may be related to the commissioning of the product, temporary movement with maintenance and storage or temporary standing (as appropriate). Based on them, the degree of mobility will be identified in relation to the specifics of the product according to the three categories, the activity is totally independent of mobility, encountered mainly for products designed to support the user, the activity is partially dependent on mobility as in the case of large appliances or the activity is totally dependent on mobility, a situation specific to products whose functionality is strictly dependent on constant user intervention. The degree of mobility will relate to the three specific situations proposed, in which the product sustains the user, as in the case of furniture, the product does not sustain and does not need sustaining, associated with products that do not involve their movement in actual use and they are not intended to sustain the user and the third situation in which the user sustains the product, this being mainly the case for small products.

Table 3.18. The analysis structure of the formal elements of the product in relation to the typology of the specific activity, proposed by the author

	The activity is completely independent of the product's mobility	The activity is partially dependent on the product's mobility	The activity is totally dependent on the product's mobility	
connex	C	C&M	C&M	The product sustains the user
auxiliary	-	C&M	C&M	
connex	-	M	-	The product does not sustain and does not need sustaining
auxiliary	-	M	-	
connex	C	C&M	C&M	The user sustains the product
auxiliary	-	M	M	

The proposed analysis is approached in the first phase for the connex direct activities, later, using the same principle, the phases are repeated for the auxiliary activities. In performing the analysis, based on Table 3.18., the connection between the type of activity involved in use and the specificity of the support ratio is established and correlated with the indices 'C' for comfort and 'M' for manoeuvrability identified in the relation corresponding to the type of activity and finally, the extent to which the formal elements of the product ensure the degree of comfort or manoeuvrability, as the case may be. In the study, manoeuvrability is considered the ability of the product to be handled (considering the set of activities involved in the relationship between product and user) and comfort being the ability to generate a pleasant experience by properly relating the form of the product to the form of the human body.

Starting from the analysis structure, in order to exemplify the proposed approach, considering the refrigerators from the connex perspective (in actual use), the activity is partially dependent on mobility and the product does not sustain and does not need sustaining. Considering the elements that the user comes into contact, the extent to which the refrigerator door is manoeuvrable (element identified in the proposed structure) is analysed. In regards to the auxiliary analysis, in this case it can be applied for commissioning or temporary movement, the activity being either totally dependent or partially dependent on mobility as the product is moved and the user sustains the product, as he is the one who controls the movement, thus in the auxiliary situation, the extent to which the general form of the product allows manoeuvrability is analysed.

When performing the analysis, it is important to distinguish between connex and auxiliary activities, as, for similar correlations, the form may be affected from both perspectives differently, both of them being also relevant.

Table 3.19. Grading structure of the ergonomic form criterion, proposed by the author

The specificity of the form from an ergonomic point of view	Associated value in general assessment C_{f2}	Likert correspondent in general assessment
The form totally hinders the use of the product	1	Total disagreement
The form mostly hinders the use of the product	2	Disagreement
The form does not facilitate or hinder the use of the product	3	Neutral
The form mostly facilitates the use of the product	4	Agreement
The form totally facilitates the use of the product	5	Total agreement

The **author proposed** the notation of the criterion considering the notions identified following the reporting of the product specificity to the analysis structure, based on that, will be noted according to Table 3.19. the extent to which the form facilitates or hinders the experience of use.

3.2.3.3. Material assessment from ergonomic perspective

In the assessment of the material from an ergonomic point of view, the extent to which the specificity and properties of the materials [16, 41, 59] affect the user experience will be established. Also, depending on the type of product, it is important to consider the risk of user exposure to potential allergens or other similar causes with high incidence, such as sensitivity to nickel, chromium, cobalt or other materials that may cause intolerances [143]. When performing the ergonomic analysis of the material it is recommended to consider especially the following aspects:

▪ Roughness and compressibility [11] - of major relevance in the analysis of the degree of comfort provided by the material, the comfort being considered both for the surface of the material by roughness and as general approach by the degree of compressibility, in which case is considered to be positive or not depending on the destination and specificity of the product;

▪ Weight - one of the most obvious aspects to consider in the ergonomic assessment of the material (the material being the main feature responsible for the weight of the product), especially since a much too high weight of the product may even involve the replacement of the material if it ends up affecting manoeuvrability and implicitly aggravate use;

▪ Electrical and thermal conductivity - the effects may be technically desirable, however may affect the quality of use experience and even the safety of the user in some cases;

▪ Transparency - in relation to the type of product, it can add value to the product and make it easier to use, or it can also be the case to affect the product and make it more difficult to use it by exposing too much detail.

Table 3.20. Grading structure of the ergonomic material criterion, proposed by the author

The specificity of the material from an ergonomic point of view	Associated value in general assessment C_{m2}	Likert correspondent in general assessment
The material totally hinders the use of the product	1	Total disagreement
The material mostly hinders the use of the product	2	Disagreement
The material does not facilitate or hinder the use of the product	3	Neutral
The material mostly facilitates the use of the product	4	Agreement
The material totally facilitates the use of the product	5	Total agreement

As can be observed, the material can also affect the product by the degree of comfort due to its roughness and compressibility as well as the degree of manoeuvrability by its weight or the ability to be, for example, non-slip or slippery depending on the desired property. The **author proposed** that the notation of the criterion to be done according to Table 3.20. indicating the extent to which the material makes it difficult or easy to use the product.

3.2.3.4. Dimensioning assessment from ergonomic perspective

The assessment of the dimensioning from an ergonomic point of view will be performed based on the anthropometric dimensions considering the specifics of the user according to the category for which the product is intended, taking into account age, height, weight, gender, race and cultural implications (anthropometric specificity in relation to the geographical indication), these being related to the type of activity in which the product will be used, the purpose being not only to facilitate the development of the activity but also to consider the safety of the user [62, 124]. The assessment of the criterion will address specific anthropometry studies [30, 57, 106, 111, 141] in relation to the specificity of the user (considering the dimensional variations of the segment for which the product is intended), taking into account the variability of anthropometric measurements [111] and it is recommended that dimensioning should accommodate the largest variant without affecting the smallest variant, thus, most anthropometry studies refer to the 95% versus 5% rule of human body measurements. When establishing a framework for anthropometric measurements it is quite difficult to assume a valid general standard as local and ethnic implications can vary greatly [3, 160], requiring separate studies for distinct ethnic groups. Regarding the study of anthropometry in Romania, not enough data are known to present a general framework. However, the reference to a standard that could involve slight variations in dimensioning due to cultural differences is still a better option than one in which anthropometry is ignored, the recommendation being to use standards as close as possible ethnically to the cultural area to which the product is dedicated. Starting from an identified anthropometric basis, for the assessment of the ergonomic dimensioning criterion, the **author proposed** the following analysis used establish the value of the associated indicator in the general assessment, in which the average variation is considered by relating the product dimensioning values to the reference anthropometric dimensions. Therefore, by using the relation (3.17), the variation of a dimensioning value e_r will be determined, after which the average variation of the considered values will be determined on the basis of formula (3.18), by relating the sum of the variations to the number of reference elements.

$$e_r = \frac{|V_{ref_r} - V_{p_r}|}{V_{ref_r}} * 100\% \tag{3.17}$$

$$V = \frac{\sum_{r=1}^{u} e_r}{u} \tag{3.18}$$

where, e_r represents the variation of the considered anthropometric element, V_{ref_r} represents the reference value of the anthropometric dimension, V_{p_r} represents the value associated with the product, V represents the average variation and u being the number of reference elements.

Table 3.21. Grading structure of the ergonomic dimensioning criterion, proposed by the author

Reference values for average variation V	Associated value in general assessment C_{d2}	Likert correspondent in general assessment
$V > 20$	1	Total disagreement
$V \in (15, 20]$	2	Disagreement
$V \in (10, 15]$	3	Neutral
$V \in [5, 10]$	4	Agreement
$V < 5$	5	Total agreement

Thus, starting from the typology of the product and the corresponding elements that have an impact in the ergonomic dimensioning, V_{ref_r} is identified based on reference anthropometric studies, and V_{p_r} will be determined by the effective measurement of the dimensions of the product. The number of considered items u will be done in relation to the specifics of the product, being recommended the analysis of as many elements as possible that can impact the user experience.

The **author proposed** the notation of the dimensioning criterion from the ergonomic perspective based on Table 3.21. in which the reference intervals for the mean variation V are presented along with their equivalent in the general assessment C_{d2}. As it can be observed, the established intervals for the V indicator do not impose an extreme strictness, as there can be dimensioning variations (which can be established in relation to the technical, aesthetic or symbolistic dimensioning) that do not majorly affect the product, therefore the purpose of the proposed analysis is to provide an assessment framework based on which is considered the extent to which the product facilitates or affects the quality of the experience itself.

3.2.4. Symbolistic assessment

3.2.4.1. Colour assessment from symbolistic perspective

The assessment of the symbolism of the colour of industrial products will be approached in relation to the categories considered in the market segment. The significance associated with a certain category is analysed from the perspective in which the user's personality is reflected in the product's personality (in this case, approached based on the colour scheme). In general, colour preferences evolve in relation to individual life experiences [68] and along with hue, both brightness and saturation are relevant factors [76, 95]. It is difficult to predict an absolute preferential pattern for a particular category, as the categories of the demographic segment often overlap and influence each other. An easy way to prioritize preferential influences is to use the hierarchy proposed in relation (3.5) previously presented in the pre-assessment study (developed in Paper 7). It is also important to delimit the assessment of the symbolism of the colour from the ergonomic one, the preferences in relation to the niche considered may be different from the generated sensation and the psychological effect that the colour may have directly on the user, in which case the effects are generally valid and influence the quality of the user experience, thus being necessary to understand how the two categories overlap and influence the final colour of the product. For example, as previously presented, warm furniture colours favour cognitive processes (ergonomic effect), but at the same time, for this example, a symbolic association with maturity may be desired, which could involve cold colours [25]. In this case, in terms of significance, the effect of maturity could also be generated by the low level of colour saturation without changing the hue or the ergonomic effects. Thus, both criteria could be met without affecting each other.

Table 3.22. Grading structure of the symbolistic colour criterion, proposed by the author

The specificity of the colour from symbolistic point of view	**Associated value in general assessment C_{c3}**	**Likert correspondent in general assessment**
The symbolism of the colour scheme strongly disadvantages the product	1	Total disagreement
The symbolism of the colour scheme relatively disadvantages the product	2	Disagreement
The symbolism of the colour scheme does not disadvantage or favour the product	3	Neutral
The symbolism of the colour scheme relatively favours the product	4	Agreement
The symbolism of the colour scheme strongly favours the product	5	Total agreement

The **author proposed** the notation of the criterion according to Table 3.22. establishing the extent to which the meaning associated with the chromatic scheme and implicitly of the colours in its composition favours the product from the perspective of the symbolism associated with the considered market segment.

3.2.4.2. Form assessment from symbolistic perspective

In evaluating the form from the perspective of meaning, the symbolic associations of the product form in relation to the specificity of the user for whom the product is intended will be considered, being correlated between the form and the cultural values associated with the product called 'intangible effect of form' assigned to the product by the user. Considering the assessment of symbolism, the **author proposed** the approaching of the form from the perspective of the following three associated categories and subcategories:

▪ The form of the general details - includes both the form of the general structure (the shape of the outer ‘shell’ of the product) and the general form of the components;

▪ The form of the ornamental details - these can be embossed and flat (situation in which the print can be analysed from the grammar perspective of the shape);

▪ The form of additional details - with reference to other formal graphic elements that can be found on the surface of the product, the category also includes elements related to the fonts and the transmitted meaning, even the graphic elements related to corporate identity.

For the three categories, more than the formal coherence (considered in the functional-auxiliary analysis), in the assessment of the criterion, the semantic attributes will be analysed considering the meaning invoked by the forms from the product composition. Interpretation can be made both on the basis of abstract representations (considering forms defined by curved lines as those defined by straight lines) and on the basis of the reproduction of recognized symbols, in which case the meaning can vary greatly depending on cultural implications [49, 101].

Table 3.24. Grading structure of the symbolistic form criterion, proposed by the author

The specificity of the form from symbolistic point of view	**Associated value in general assessment C_{f3}**	**Likert correspondent in general assessment**
The form's symbolism strongly disadvantages the product	1	Total disagreement
The form's symbolism relatively disadvantages the product	2	Disagreement
The form's symbolism does not disadvantage or favour the product	3	Neutral
The form's symbolism relatively favours the product	4	Agreement
The form's symbolism strongly favours the product	5	Total agreement

The **author proposed** the notation of the criterion based on Table 3.24. establishing the extent to which the significance of the formal elements of the product (general, ornamental and additional) favours or affects the considered product.

3.2.4.3. Material assessment from symbolistic perspective

The assessment starts from the determination of the factors that influence the symbolism associated with the material, considering the way in which they interact in the generation of a certain meaning [79]. Thus, the **author proposed** the analysis of the significance of the material from the perspective of the three following categories:

a) Associations related to the purpose and context of use - The intended use may influence the significance of the material in relation to the personality of the product [147]. For example, for a car a metal body generates the feeling of safety and power (associations related to technical aspects), but in the case of products with fewer technical restrictions of the material in relation to the purpose of use, the significance of the material is an aspect more complex, considering metal as an example and in this case, for a household interior door, the material can evoke the feeling of isolation. It is also relevant to consider the material in relation to the honesty of the design, especially in the case of products defined by different materials in the composition, where the symbolism associated with the material of the ornamental details must be in relation to the overall symbolism of the product.

b) Associations related to the evoked sensation - Considering strictly the material in direct contact to the user, meanings can also be generated in relation to the evoked sensations or emotions [29]. Although they may be subjective, the associated sensations may be due to the users' accumulated experiences over time with products defined by the materials in question. For example, metal tends to be associated with aggression, hardness, coldness or masculinity, as opposed to wood which is associated with warmth, naturalness or maturity [26, 34].

c) Associations related to the specificity of the user - The symbolism of the material can be considered from the perspective of personal preferences, in a broad context, this means relating to the market segment and identifying the predominant associations of significance for a particular segment, preferential affinities can be influenced by age, gender, socioeconomic status or cultural implications [7, 80].

Table 3.25. Grading structure of the symbolistic material criterion, proposed by the author

The specificity of the material from symbolistic point of view	Associated value in general assessment C_{m3}	Likert correspondent in general assessment
The material's symbolism strongly disadvantages the product	1	Total disagreement
The material's symbolism relatively disadvantages the product	2	Disagreement
The material's symbolism does not disadvantage or favour the product	3	Neutral
The material's symbolism relatively favours the product	4	Agreement
The material's symbolism strongly favours the product	5	Total agreement

The **author proposed** the notation of the criterion and the reporting to the general assessment on the basis of Table 3.25., being recorded the meanings associated with the material both by referring to a category in question and the consistency of the associations obtained for the three categories.

3.2.4.4. Dimensioning assessment from symbolistic perspective

The symbolism of dimensioning is approached from the perspective of the influence that the dimensions of certain elements of the product have on the role of use. Thus, changing the length of certain elements for the same type of product determines the dimensioning to differentiate the product according to the purpose and the specificity of the user for whom the product is intended. In the case of furniture, the change in purpose depending on the dimensioning is influenced by both anthropometric sizes (for example, a very small bed or chair will be automatically associated with a piece of furniture for children) and the circumstances of use, for instance, changing the length of the elements of a table, by reducing the size of the legs and board of a product intended for meal serving, the object generated by such smaller dimensions will be associated with a coffee table, even for this, compared to a console table a difference of associated significance is observed, the dimensioning between the two being distinct both by their height and general width. An eloquent case of exemplifying the meaning associated with products by dimensioning variations is that of wine glasses, in which case the material and colour (clear glass) or overall form are not altered, the meaning shows variations only in relation to changing the dimension of its components. Starting from the dimensioning of the wine glass for tasting that is in line with the standard ISO 3591:1977 [179] (the need for a standard tasting glass is justified by the fairness of the evaluation of different types of wines), the changes occurring in the dimensioning of the elements of the glass are related to the degree of oxygenation of the wine and implicitly to the olfactory experience, effects desired or not in relation to the specificity of the type of wine considered [108]. Thus, starting from a practical purpose of improving the quality of the use experience, the significance of the glasses specific to a type of wine has become over time an association of significance in relation to the dimensioning of the components. For the same dimensioning of the height of the glass and the leg, if the lateral size of the cup of a glass of red wine is changed, its dimensions correspond to those of a glass of white wine, decreasing even more the size, the glass becomes associated with a glass of sparkling wine. Also, considering the example of the red wine glass compared to a glass of brandy this time, the side dimensions of the glasses are similar, but the overall height dimensions change.

Table 3.26. Grading structure of the symbolistic dimensioning criterion, proposed by the author

The specificity of dimensioning from symbolistic point of view	Associated value in general assessment C_{d3}	Likert correspondent in general assessment
The symbolism of dimensioning strongly disadvantages the product	1	Total disagreement
The symbolism of dimensioning relatively disadvantages the product	2	Disagreement
The symbolism of dimensioning does not disadvantage or favour the product	3	Neutral
The symbolism of dimensioning relatively favours the product	4	Agreement
The symbolism of dimensioning strongly favours the product	5	Total agreement

When carrying out the analysis, the destination of use will be considered depending on the specifics of the product, considering the target segment and the expected context of use of the product. Based on them, the dimensions generally associated with the product type will be related to the dimensions of the assessed product, taking into account the message sent by the product in relation to its dimensioning. The **author proposed** that, for the grading of the criterion, the scale of the product (or its elements) in relation to the associated symbolism to be considered, establishing according to Table 3.26. the extent to which the significance of dimensioning favours or not the product.

3.2.5. Aesthetic assessment

3.2.5.1. Colour assessment from aesthetic perspective

From an aesthetic perspective, colour is approached in relation to the level of harmony associated with the colour scheme. At the basis of the selection of harmonious colour combinations are studies starting from the 'colour wheel' related to the subtractive system [71, 130, 134]. Thus, the assessment of the criterion starts from the analysis of the degree of compatibility of the colours identified in the chromatic scheme of the product, the indicator c_t being noted based on Table 3.27. considering the level of harmony generated by the combination of colours.

Table 3.27. Grading structure of the specifics of the chromatic scheme in relation to the degree of compatibility, proposed by the author

Colour scheme's degree of harmony	Value of c_t indicator
The colour combination generates major discordance	1
The colour combination relatively generates discordance	2
The colour combination generates minimal concordance	3
The colour combination generates average concordance	4
The colour combination generates concordance to a large extent	5

Thus, harmony is approached firstly from the perspective of colour selection, however there is also the possibility to perform a quantitative and not only selective analysis of the degree of chromatic harmony. Starting from Newton's studies on light dispersion, Goethe J. W. [54] is the first to study the harmony related to surfaces and associate them with numerical values, following that, Itten J. [71] establishes values for contrasting primary and secondary colours, as presented in relations (3.19)..(3.21) [71], these being represented graphically in the first column of Fig. 3.8.

$$Yellow : Violet = 3 : 9 = {}^{1}/_{4} : {}^{3}/_{4} \quad (3.19)$$

$$Orange : Blue = 4 : 8 = {}^{1}/_{3} : {}^{2}/_{3} \quad (3.20)$$

$$Red : Green = 6 : 6 = {}^{1}/_{2} : {}^{1}/_{2} \quad (3.21)$$

Considering these, in order to identify harmony relations not only for the contrasting colours and even more to adapt the concept to the product assessment, the **author proposed** in the paper 'A study on product color ratio based on aesthetic principles in industrial design assessment' [Paper 5] the following analytical approach, in which the degree of harmony associated with the product in relation to the proportion of surface area can be determined. Industrial products are often defined by colourless surfaces, so it was necessary to adapt the colour intensity system to non-colour variations. The greys thus obtained from Fig. 3.8. were related to a grading system from 1 to 10, the remaining spaces being completed with the corresponding variations in intensity, the minimum value being 1 for white and the maximum 10 for black (as shown in Fig. 3.9.).

Fig. 3.8. Colour ratios adapted to grey scale, author proposal [Paper 5]

Fig. 3.9. Grey scale ratios, author proposal [Paper 5]

The values associated with colours and non-colours were structured and presented in Table 3.28. on the basis of which the correspondence relations between the indicators C_i will be deduced in relation to the specific colour and the associated value v_i.

Table 3.28. Values associated with colours and non-colours [Paper 5]

Colour	Colour indicator C_i	Associated value v_i
Red	R	6
Orange	O	4
Yellow	Y	3
Green	G	6
Blue	B	8
Violet	V	9
White	Wh	1
Grey	Gr	2..9
Black	Bk	10

In order to adapt the previous proposed system to the aesthetic assessment of the product colour, the first step is to determine the dominant colours that define the product (small technical indicators on the product surface are excluded from the analysis, as they have significance in relation to the message that concerns safety conditions).

For a product considered in the analysis, based on the colours identified, the relative coverage of a colour in relation to the total area considered will be estimated, and the deviation between them and the associated values in the proposed system according to relations (3.22) and (3.23) will be determined, the degree of harmony between the colours being generated by the ratio of the values of an indicator to their sum (associated with the total surface coverage).

$$C \in \{R, G, B \dots Wh, Bk\} \quad (3.22)$$

$$\frac{C_1}{v_1} = \frac{C_2}{v_2} = \dots = \frac{C_n}{v_{n_*}} = \frac{100}{\sum_{i=1}^{n_*} v_i} \quad (3.23)$$

where, C is the colour indicator, v corresponds to the associated value for a certain colour according to Table 3.28., n_* is the number of colours considered in the relation and i is the indicator of a considered colour.

Thus, in order to determine the S_P value (based on 3.25 relation) between the coverage degree of the product areas and the values determined within the system, the analysis starts from x_i, that was obtained after adapting the relation (3.23) to the form presented in (3.24). For the indicator y_i, following the analysis of the colour scheme of the product, a numerical value will be assigned in relation to the estimated surface coverage for each concerned colour.

$$x_i = \frac{v_i * 100}{\sum_{i=1}^{n_*} v_i} \quad (3.24)$$

$$S_P = \sqrt{\frac{\sum_{i=1}^{n_*} (x_i - y_i)^2}{n_* - 1}} \quad (3.25)$$

where, S_P represents the total deviation associated with the chromatic harmony ratio of the product surface, x_i is the recommended coverage ratio according to the proposed system of a colour, y_i represents the estimated coverage ratio in relation to the total area of the product, n_* is the number of colours in the relation and i is the indicator of a considered colour.

According to Table 3.29., after the reporting of the previously determined value at set intervals S_P, the analysis indicator for the degree of harmony of the chromatic scheme considered in the quantitative ratio c_r will be noted, this being subsequently necessary in determining the final value of the criterion.

Table 3.29. Reporting the structure of deviation S_P to the indicator c_r, proposed by the author

Reference interval S_P	Numerical value associated with c_r indicator
$S_P \in (0.8 , 1]$	1
$S_P \in (0.6 , 0.8]$	2
$S_P \in (0.4 , 0.6]$	3
$S_P \in (0.2 , 0.4]$	4
$S_P \in [0 , 0.2]$	5

In order to analyse the way that the variations of colour ratios are interpreted by users, a study was conducted in which a series of 15 different products are presented in groups of three, as shown in Table 3.20. For the proposed products, the changes were made only on the colour scheme, all other dimensioning elements, form or material being unchanged. Moreover, for each considered series, one of the three products is thus defined by the minimum deviation as: A series – P_2, B series – P_2, C series – P_1, D series – P_3, E series – P_1, the other two products in the series being defined by variations in deviation of the colour harmony ratios according to S_P indicator. The study was performed on a sample of 78 persons from various fields of activity (IT, financial, advertising, sales, economic etc.), the respondents being 15.4% under the age of 25, 76.9% with the age between 25 and 45 years and 7.7% over the age of 45. Regarding the educational level, 74.4% of the respondents have higher education and the gender ratio is thus divided, 70% women and 30% men. In completing the questionnaire, respondents were tasked with identifying the product considered most attractive among the three options for each proposal in question.

Based on the data obtained in the study (according to Paper 5), a first analysis is to verify the existence of noticeable differences between the present groups, being applied in this case the multivariate analysis MANOVA considering independent variables gender, age and educational level with dependent variables as the considered series from the study. Thus, the null hypothesis was formulated according to which no differences can be noticed between groups. The data obtained were analysed in the SPSS software program [185], identifying the statistical relevance of the interaction effect between the three independent variables on the combined dependent variables, the results being reported as follows $F(4, 59) = 2.869$, $p = 0.031$, Wilks' $\Lambda = 0.837$, partial $\eta^2 = 0.163$, the null hypothesis being rejected in this case. Further analysis of the main effects (considering a single independent variable) had no statistically relevant results and the null hypothesis could not be rejected, so in this case no direct effects of the independent variables (gender, age and educational level) on the preferences associated with the five series were identified.

With regard to the second analysis, it was verified that there was a link between the deviation values associated with the series and the preferences identified in the study, analysing the extent to which the products defined as minimum deviations (according to the previously proposed approach to harmony in relation to the surface coverage ratios) are assessed to the detriment of those defined as high value of the deviation, in which case a correlation study of the data obtained is applicable. In the case of three of the five proposals, respondents' preferences corresponded to the determined minimum deviation, B series (0.05/39.70%), D series (0.02/41.00%) and E series (0.04/57.70%), for the other two series, secondary deviation values were thus associated, A series (0.03/34.60%) and C series (0.02/34.60%). Since quantitative variables are considered in the analysis and the correlation is thus based on two continuous variables, the results obtained were reviewed based on Pearson analysis and validated using SPSS statistical software [185], the results being reported as follows: $r(13) = -0.613$, $p = 0.015 \rightarrow r > \pm 0.5$, $p < 0.05$, and as can be observed, the value obtained for the correlation indicator is the same and statistically applicable. Thus, the relevance of the study can be interpreted, the degree of correlation being relatively high and associated with a negative sense of correlation (desired effect in this case, relating the maximum preference to the minimum deviation).

Considering the presented notions, the **author proposed** the notation of the criterion of colour aesthetics based on the E_c indicator according to relation (3.27) by considering the average between the degree of colour compatibility (considered as selective harmony) based on the value of c_t indicator that was obtained from Table 3.27. and the optimal surface coverage ratio (considered quantitative harmony) based on the value of c_r indicator that was obtained from Table 3.29.

$$E_c = \frac{c_t + c_r}{2} \tag{3.27}$$

where, E_c represents the indicator associated with the aesthetic colour criterion, c_t represents the chromatic compatibility ratio and c_r represents the degree of harmony of the chromatic scheme considered in the quantitative ratio.

Table 3.32. Grading structure of the aesthetic colour criterion, proposed by the author

Associated value of E_c indicator	**Associated value in general assessment C_{c4}**	**Likert correspondent in general assessment**
$E_c = 1$	1	Total disagreement
$E_c \in (1, 2]$	2	Disagreement
$E_c \in (2, 3]$	3	Neutral
$E_c \in (3, 4]$	4	Agreement
$E_c > 4$	5	Total agreement

Thus, the **author proposed** the grading of the colour aesthetic criterion based on Table 3.32. considering the average value obtained for E_c indicator and its relation to the corresponding equivalent in the general assessment C_{c4}. It should be mentioned that, if the product is absolutely monochrome, a numerical value for colour cannot be assigned from an aesthetic perspective, as the superiority of one colour over another in aesthetics cannot be appreciated (whether they are considered colours or non-colours). Although the colour of the product can be associated with personal preferences or elements of significance, in this case, within the dimension of symbolism it will be assigned a value for the colour in question, also the other technical and ergonomic perspectives remain valid in colour assessment, depending on the extent to which the criterion can be applied for that type of product.

3.2.5.2. Form assessment from aesthetic perspective

In aesthetic assessment, the implications that can generate harmony from the perspective of visual balance of the form are considered. In previous studies on the aesthetics of form, presented along with their degree of applicability, form is approached as follows:

- Plane perspective - One of the most known approaches of form aesthetics is that of Birkhoff [13] also called the 'formula for quantifying aesthetic measure', in which, as presented in relation (3.28), the aesthetic measure is represented as the ratio between order and complexity, order being in turn defined by the sum of factors associated with visual harmony.

$$M = \frac{O}{C} = \frac{V+E+R+HV-F}{C} \tag{3.28}$$

for the given formula, M is aesthetic measure, O is order, C is complexity, V represents vertical symmetry, E represents equilibrium, R represents the rotational symmetry, HV is the reference to a horizontal-vertical network and F represents the unsatisfactory form [13].

From Birkhoff's formula derives a series of approaches in the aesthetics of form that try to improve the algorithm [132] or use the same principle of analysis but approach the concepts only from a linear perspective [100, 161]. Thus, the main disadvantage of Birkhoff's formula is highlighted by the limitation of the application on two-dimensional shapes. Although it presents relevant aspects in the product assessment, it applies only on the contour of the product and not on the general three-dimensional shape (considered as form).

- Spatial perspective - adapting to three-dimensional approaches proves to be quite difficult and mostly involves changes to the ‘aesthetic size’ [121], even simplifying the assessment criteria for symmetry, minimalism and cohesion [88]. On the other side, in the aesthetic assessment of the product form from a spatial perspective, in the situation where improvement is desired using the principle of 'golden ratio' [27], the principles considered in the generation of form are applicable, however, in this thesis they are addressed separately in the aesthetics dimensioning separated from the form assessment and as will be seen, a product whose form is generated by complex relations of harmony is not necessarily valid from the perspective of dimensioning. Considering the applicability of the 'Fibonacci Spiral' [42] on the shape of the product, using the same concept in numerical manner related to proportionality, it is observed that it no longer applies in the same way as will be seen in the next section (the 'spiral' being considered a graphic element, and the numerical version seen as 'ratio').

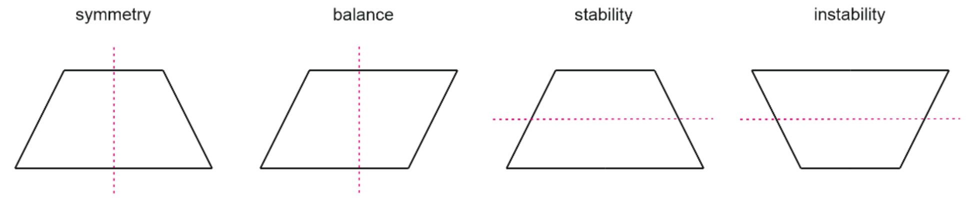


Fig. 3.10. Presentation of elementary aesthetic principles of form

Considering the previous studies along with principles of visual aesthetics [61, 113], the **author proposed** the following approach of form aesthetic assessment, the product being approached from a three-dimensional perspective based on the five categories presented in Table 3.33.

Table 3.33. Analysis structure of form from aesthetic perspective, proposed by the author

	A	B	C	D	E
	0				
1	Symmetry from the perspective of one side	0			
2	Symmetry from the perspective of two sides	Minimum degree of form balance	0		
3	Symmetry from the perspective of three sides	Medium degree of form balance	The form has a minimum degree of fluidity	0	
4	Symmetry from the perspective of four sides	High degree of form balance	The form has a medium degree of fluidity	Relatively unstable form	0
5	Symmetry from the perspective of more than four sides	Very high degree of form balance	The form has a high degree of fluidity	Relatively stable form	Complexity of form

In Fig. 3.10. the way of approaching the aesthetic principles embedded in the analysis structure is presented, the difference between symmetry and balance being exemplified on the left side and stability and instability on the right side. In addition, two categories of form analysis were added, the degree of fluidity presented in category C and complexity ratios of harmony in category E, as seen in Table 3.33. It should be mentioned that unity is integrated in category C, and proportionality will be assessed in the aesthetic phase of dimensioning.

The categories of form assessment are described as follows:

Category A. Vertical symmetry - Regardless of the nature of the product, the form will be considered from the perspective of six sides, analysing the number of identified sides in which the product has vertical symmetry and if the product does not have vertical axes of symmetry, the value of the category is zero.

Category B. Balance - Considering a vertical axis, balance represents a manner of equilibrium of elements. Its absence will be marked with zero, otherwise the category will be marked based on the four steps associated with the degree of balance.

Category C. Degree of fluidity - It is considered the general form along with the relation between it and the additional elements (ornamental details or control operators) and if the fluidity of the form is absent the value of the category is zero. The proposed category does not associate superiority with organic forms, another way of interpreting fluidity is from the perspective of unity or formal consistency.

Category D. Stability - Considering a horizontal axis (in the vertical position of the product), the category will have zero value if the product is associated with instability and has a very small base, the minimum value is the situation where the bottom is relatively smaller compared with the upper one and maximum value if the lower part is equal or higher compared to the upper one.

Category E. Complexity - Given the general form, complexity is considered in the situation where the form of the product generates interest through its structure, without the dynamicity of the form affecting the degree of harmony.

According to Table 3.34., based on the values assigned to the form of the product for the five categories, the indicator associated with the aesthetic criterion of the form is determined based on the relation (3.29), summing up the values established for each category.

$$E_f = f_A + f_B + f_C + f_D + f_E \tag{3.29}$$

where, E_f represents the indicator for form aesthetics, f_A is the value assigned for symmetry, f_B is the value assigned for balance, f_C is the value assigned for fluidity, f_D is the value assigned for stability and f_E is the value assigned for complex elements of harmony.

Table 3.34. Grading structure of the aesthetic form criterion, proposed by the author

Associated value of E_f indicator	Associated value in general assessment C_{f4}	Likert correspondent in general assessment
$E_f < 5$	1	Total disagreement
$E_f \in (5, 10]$	2	Disagreement
$E_f \in (10, 15]$	3	Neutral
$E_f \in (15, 20]$	4	Agreement
$E_f \in (20, 25]$	5	Total agreement

The **author proposed** the marking of the criterion based on Table 3.34. by reporting the values obtained for E_f indicator to the associated values in general assessment. As can be seen, the intervals set for the total agreement do not impose a maximum rank value of 5 for all categories (shown in Table 3.33.), as the proposed structure allows a range of flexibility of form variations (they may be related to the specificity or personality of the product), however the weighted elements that have an impact on the aesthetics of the form are considered.

3.2.5.3. Material assessment from aesthetic perspective

From an aesthetic point of view, the material is often approached from a visual perspective, however, in recent years more and more importance is given to sensory analysis, especially haptic aesthetics as the relation between the material and the sensation generated by contact [20]. Considering the previous studies regarding the sensory study of the material [81, 148, 165], it is recommended that in the aesthetic assessment the material should be analysed according to the following approaches:

- Visual analysis – it will be analysed the degree of harmony generated by the model (print) of the material along with its optical properties;
- Haptic analysis – will be considered the tactile sensation generated in direct relation to the material, including the roughness and temperature of the material, analysing the extent to which it generates the sensation of pleasure;
- Auditory analysis – the sensation perceived in relation to the sound generated by the product in the process of use will be analysed;
- Olfactory analysis – if it is the case, the product will be analysed from the olfactory perspective and the generated sensation;
- Gustatory analysis – although it may seem exhaustive, for certain classes, taste analysis can also be important, especially in situations where the material is desired to be vapid.

For the five proposed perspectives of aesthetic analysis of the material, certain associated attributes are positive or negative in relation to the product typology and the absence of certain effects such as tasteless or odourless is not necessarily a negative aspect, as they may be desired effects for a type of product in question.

Table 3.35. Grading structure of the aesthetic material criterion, proposed by the author

The specificity of material from aesthetic point of view	Associated value in general assessment C_{m4}	Likert correspondent in general assessment
The sensory experience strongly disadvantages the product	1	Total disagreement
The sensory experience relatively disadvantages the product	2	Disagreement
The sensory experience does not disadvantage or favour the product	3	Neutral
The sensory experience relatively favours the product	4	Agreement
The sensory experience strongly favours the product	5	Total agreement

The **author proposed** the marking of the criterion according to Table 3.35. establishing the extent to which the sensory experience associated with the material favours the product.

3.2.5.4. Dimensioning assessment from aesthetic perspective

In the assessment of the aesthetic dimensioning, the degree of dimensional coherence of the product elements will be approached, being considered both its total size and the dimensioning of the components, analysing to what extent the dimensioning thus approached generates harmony. Unlike the conceptual phase, in which the designer has unlimited possibilities of aesthetic integration for the dimensioning ratios, ratios that can be as subtle or even imperceptible at a certain level but ultimately generate the feeling of harmony, in assessment, of all the proposed criteria, the aesthetic dimensioning could be the most difficult to identify. In order to facilitate their identification, the **author proposed** the following perspective by approaching the assessment of aesthetic dimensioning on the basis of two categories. The analysis starts from category A for which the principles of proportionality regarding the following types of relations are considered:

a) Proportional division - The dimensioning elements of the product will be analysed determining if there are proportional division ratios, such as the multiple of 2, 3, 4 (on the principle of those in base 2), 5 or 7 etc., being recommended to give special attention to the numerical ratios also encountered in the human body such as those in base 2 (or multiple of 2) or base 5.

b) Progressive proportionality - The linear elements of the product will be considered, based on which, it will be determined the possibility of identifying dimensioning elements based on the arithmetic progression according to the relation (3.30) or the geometric progression according to the relation (3.31).

$$d_e = d_{e-1} + c \tag{3.30}$$

for the given formula, d_e is representative of a term of arithmetic progression, e represents the position of the term and c is the ratio of arithmetic progression.

$$d_e = d_{e-1} * c \tag{3.31}$$

for the given formula, d_e is representative of a term of geometric progression, e represents the position of the term and c is the ratio of geometric progression.

c) Proportionality based on complex ratios - Starting from the principles stated by Euclid [45], by the relative reporting of two segments, identified in this case by d and D, they are considered as representative for the golden ratio if they meet the condition stated in the relation (3.32). If the relation (3.32) is equivalent to φ (representative indicator for the golden ratio), the equation will take the form presented in relation (3.33) and will have two real solutions, for the positive one φ having a value of approximatively 1,618, also called the ‘golden number’. Starting from this concept, the ‘golden sequence’ represented in relation (3.34) was enunciated, in which a given term is represented by the sum of the two previous ones.

$$\frac{d}{D} = \frac{D}{d + D} \tag{3.32}$$

$$\frac{d}{D} = \frac{D}{d + D} = \varphi \leftrightarrow \varphi^2 - \varphi - 1 = 0 \tag{3.33}$$

$$S_F = \{0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, \dots\} \tag{3.34}$$

for the given formulas, d is representative for the dimensioning of the small segment, D is representative for the dimensioning of the big segment, φ is the equivalent associated with the 'golden number' and S_F is representative of the 'golden sequence' [114].

With regards to category B, the extent to which the proportionality of the product elements respect structural coherence will be considered, as a large scale compatibility being associated with the balance between the feeling of robustness and elegance generated by the dimensioning of the product. An example of easy identification of structural coherence is the harmonious report of the dimensions of control operators related to the dimensioning of the main body of the product.

Table 3.36. Analysis structure of aesthetic dimensioning, proposed by the author

	Category A	Category B
1	Harmonious dimensioning ratios cannot be identified	Proportionality does not comply with structural coherence
2	Progressive proportionality ratios based on arithmetic progression	Proportionality complies with structural coherence to a small extent
3	Progressive proportionality ratios based on geometric progression - proportional division for secondary ratios (other than elementary ones)	Proportionality relatively complies with structural coherence
4	Proportional division for the elementary ratios (ratio 2,3 and 5)	Proportionality complies with structural coherence to a large extent
5	Proportionality ratios based on complex strings	Proportionality complies with structural coherence to a very large extent

In the assessment of the criterion, the dimensioning elements of the product will be analysed based on the two proposed categories, according to Table 3.36., the assigned values being used to determine the indicator E_d according to the relation (3.35). Regarding the rating of category A, in the case where proportionality ratios are identified in several subcategories, the situation defined by the highest weight will be noted.

$$E_d = \frac{d_A + d_B}{2} \tag{3.35}$$

where, E_d represents the indicator for the aesthetics of dimensioning, d_A is the value assigned to the proportionality ratio category and d_B is the value assigned to the structural coherence category.

Table 3.37. Grading structure of the aesthetic material criterion, proposed by the author

Associated value of E_d indicator	**Associated value in general assessment C_{d4}**	**Likert correspondent in general assessment**
$E_d = 1$	1	Total disagreement
$E_d \in (1, 2]$	2	Disagreement
$E_d \in (2, 3]$	3	Neutral
$E_d \in (3, 4]$	4	Agreement
$E_d > 4$	5	Total agreement

The **author proposed** the marking of the criterion based on Table 3.37. by reporting the value obtained for the E_d indicator to the value associated in the general assessment.

3.3. ASSESSMENT INTERPRETATION

3.3.1. Determination of assessment indicators

Based on the grading of the criteria, the indicators are determined in order to assign a numerical value associated with the design of the considered product, this being reflected in both the final assessment grade N_{FD} (in which the reporting is done for all five dimensions) as well as for the indicators I_{cr} obtained for each feature, on the basis of which recommendations can be made to improve the product (according to the reference range) taking into account the influence relations between them that can be both physical (direct) and perceptual.

For each of the four considered features, four criteria are related to the dimension in question, for example, colour is a feature of the product, but technical colour is addressed as a criterion. If, for a criterion, the assessment cannot be performed (situation influenced by the product typology), as a feature is approached from four different perspectives, the neutrality of the rating or its direct exclusion from the assessment would influence the comparative interpretation of the values obtained for the indicators I_{cr} indicators, thus being necessary to report on the same numerical scale of analysis. As a result, $P_{\max Total}$ indicators were introduced (the maximum total value corresponding to the weighted values of the criteria) and $P_{\max D_o}$(the maximum weighted value of a dimension for which the criterion cannot be assessed), based on them, using the relation (4.41) in determining the assessment indicator I_{cr}, from the value of $P_{\max Total}$ the value of $P_{\max D_o}$ will be decreased, therefore I_{cr} can take maximum value even in the situation where it is not possible to mark a criterion, which still allows the comparative assessment of the values obtained for features.

When determining the assessment indicators and completing the format, the assessment starts from establishing the corresponding class and identifying the values of importance of the dimensions. Thus, based on Table 3.1. (according to Paper 4) previously presented in the beginning of 'Chapter 3', were determined and presented in Table 3.40. the corresponding values of dimensions importance I_D for each class considered among the 32 available Locarno classes, in the table being presented a brief description of the classes considered in the 11th edition [180].

Regarding the application of the method depending on the type of approach, whether the criteria are graded in the standard version by referring to antagonistic attributes (according to the format presented in Table 3.38.) or in the extended version by considering additional studies associated with the criteria (according to the format presented in Table 3.39 by completing the observation fields based on the criteria analysis under the form proposed in Subchapter 3.2.), the determination of the indicators will be performed on the same principle, based on the structure presented in Table 3.41. In correspondence with it, following the grading of the criteria, the proposed calculation steps are completed, obtaining the values for the final assessment indicator N_{FD} and for I_{cr} indicators that are correspondent to the comparative assessment according to the values obtained for I_{colour}, I_{form}, $I_{material}$ and $I_{dimensionining}$. Based on the values thus obtained during the phase of indicators determination, along with the functional correspondent C_F/E_F considered in relation to the degree of deepening desired for the assessment, in the following phases will be presented the modalities of assessment data analysis and reporting of the results.

Table 3.38. Assessment format in the standard version of the method, proposed by the author

product photo

Class:
Product name:

Dimension		Total disagreement	Disagreement	Neutral	Agreement	Total agreement	
FUNCTIONAL	Nonfunctional	○	○	○	○	○	Functional
TECHNICAL							
Colour	Not in accordance with technical standards	○	○	○	○	○	In accordance with technical standards
Form	Unsuitable to purpose	○	○	○	○	○	Suitable to purpose
Material	Precarious	○	○	○	○	○	Durable
Dimensioning	Does not ensure safe use	○	○	○	○	○	Ensures safe use
ERGONOMIC							
Colour	Not adapted to the environment	○	○	○	○	○	Adapted to the environment
Form	Not adapted to the user's form	○	○	○	○	○	Adapted to the user's form
Material	Does not provide comfort	○	○	○	○	○	Provides comfort
Dimensioning	Not adapted to the user's dimensions	○	○	○	○	○	Adapted to the user's dimensions
SYMBOLISM							
Colour	Noncompliant with the target segment	○	○	○	○	○	Compliant with the target segment
Form	Noncompliant with the target segment	○	○	○	○	○	Compliant with the target segment
Material	Noncompliant with the target segment	○	○	○	○	○	Compliant with the target segment
Dimensioning	Noncompliant with the target segment	○	○	○	○	○	Compliant with the target segment
AESTHETIC							
Colour	Nonharmonious	○	○	○	○	○	Harmonious
Form	Unbalanced	○	○	○	○	○	Balanced
Material	Unpleasant to the touch	○	○	○	○	○	Pleasant to the touch
Dimensioning	Disproportionate	○	○	○	○	○	Proportionate

Table 3.39. Assessment format in the extended version of the method, proposed by the author

product photo

Class:
Product name:

Dimension	**Total disagreement**	**Disagreement**	**Neutral**	**Agreement**	**Total agreement**
FUNCTIONAL	○	○	○ *Observations*	○	○
TECHNICAL					
Colour	○	○	○ *Observations*	○	○
Form	○	○	○ *Observations*	○	○
Material	○	○	○ *Observations*	○	○
Dimensioning	○	○	○ *Observations*	○	○
ERGONOMIC					
Colour	○	○	○ *Observations*	○	○
Form	○	○	○ *Observations*	○	○
Material	○	○	○ *Observations*	○	○
Dimensioning	○	○	○ *Observations*	○	○
SYMBOLISM					
Colour	○	○	○ *Observations*	○	○
Form	○	○	○ *Observations*	○	○
Material	○	○	○ *Observations*	○	○
Dimensioning	○	○	○ *Observations*	○	○
AESTHETIC					
Colour	○	○	○ *Observations*	○	○
Form	○	○	○ *Observations*	○	○
Material	○	○	○ *Observations*	○	○
Dimensioning	○	○	○ *Observations*	○	○

Table 3.40. The values of importance of the assessment dimensions in relation to the specific class, adaptation from Paper 4, developed by the author

No.	Locarno Class[1]	I_F	I_T	I_{Er}	I_S	I_{Es}
1	"Foodstuffs"	30%	15%	20%	10%	25%
2	"Articles of clothing and haberdashery"	30%	10%	15%	20%	25%
3	"Travel goods, cases, parasols (...)"	30%	10%	25%	20%	15%
4	"Brushware"	30%	20%	25%	10%	15%
5	"Textile piecegoods, artificial and natural (...)"	30%	10%	15%	20%	25%
6	"Furnishing"	30%	15%	25%	10%	20%
7	"Household goods"	30%	10%	25%	15%	20%
8	"Tools and hardware"	30%	25%	20%	15%	10%
9	"Packages and containers for transport (...)"	30%	20%	25%	15%	10%
10	"Clocks and watches (...)"	30%	20%	15%	10%	25%
11	"Articles of adornment"	30%	10%	15%	20%	25%
12	"Means of transport or hoisting"	30%	25%	20%	15%	10%
13	"Equipment for production (...) electricity"	30%	25%	20%	15%	10%
14	"Recording, communication (...) equipment"	30%	20%	25%	10%	15%
15	"Machines"	30%	25%	20%	10%	15%
16	"Photographic, cinematographic (...) apparatus"	30%	25%	20%	10%	15%
17	"Musical instruments"	30%	20%	15%	25%	10%
18	"Printing and office machinery"	30%	20%	25%	15%	10%
19	"Stationery and office equipment (...)"	30%	10%	25%	15%	20%
20	"Sales and advertising equipment, signs"	30%	15%	25%	10%	20%
21	"Games, toys, tents and sports goods"	30%	20%	25%	10%	15%
22	"Arms, pyrotechnic articles (...)"	30%	25%	20%	15%	10%
23	"Fluid distribution equipment (...)"	30%	25%	20%	10%	15%
24	"Medical and laboratory equipment"	30%	25%	20%	10%	15%
25	"Building units and construction elements"	30%	20%	25%	10%	15%
26	"Lighting apparatus"	30%	20%	10%	15%	25%
27	"Tobacco and smokers' supplies"	30%	10%	15%	25%	20%
28	"Pharmaceutical and cosmetic products (...)"	30%	20%	25%	10%	15%
29	"Devices and equipment against fire hazards (...)"	30%	25%	20%	15%	10%
30	"Articles for the care and handling of animals"	30%	20%	25%	10%	15%
31	"Machines and appliances for preparing food (...)"	30%	25%	20%	10%	15%
32	"Graphic symbols (...) ornamentation"	30%	15%	10%	25%	20%

In case it is difficult to determine the class of a type of product considered in the assessment, it is recommended to consult the Locarno classification on the official website wipo.int [180], in which the related subclasses are also presented.

[1] https://www.wipo.int/classifications/locarno/en/

Table 3.41. Structure of determination for the FTESE indicators, proposed by the author

Class: Product name:					
I_D %	**Dimension**	D_{max}	C_*	P_*	P_D
$I_F =$	**FUNCTIONAL**	$D_{max\,F} =$	$C_F =$	–	$P_F =$
$I_T =$	**TECHNICAL**	$D_{max\,T} =$	$C_{max} =$	$P_{max\,T} =$	$P_T =$
	Colour		$C_{c1} =$	$P_{c1} =$	
	Form		$C_{f1} =$	$P_{f1} =$	
	Material		$C_{m1} =$	$P_{m1} =$	
	Dimensioning		$C_{d1} =$	$P_{d1} =$	
$I_{Er} =$	**ERGONOMIC**	$D_{max\,Er} =$	$C_{max} =$	$P_{max\,Er} =$	$P_{Er} =$
	Colour		$C_{c2} =$	$P_{c2} =$	
	Form		$C_{f2} =$	$P_{f2} =$	
	Material		$C_{m2} =$	$P_{m2} =$	
	Dimensioning		$C_{d2} =$	$P_{d2} =$	
$I_S =$	**SYMBOLISM**	$D_{max\,S} =$	$C_{max} =$	$P_{max\,S} =$	$P_S =$
	Colour		$C_{c3} =$	$P_{c3} =$	
	Form		$C_{f3} =$	$P_{f3} =$	
	Material		$C_{m3} =$	$P_{m3} =$	
	Dimensioning		$C_{d3} =$	$P_{d3} =$	
$I_{Es} =$	**AESTHETIC**	$D_{max\,Es} =$	$C_{max} =$	$P_{max\,Es} =$	$P_{Es} =$
	Colour		$C_{c4} =$	$P_{c4} =$	
	Form		$C_{f4} =$	$P_{f4} =$	
	Material		$C_{m4} =$	$P_{m4} =$	
	Dimensioning		$C_{d4} =$	$P_{d4} =$	
		$P_{T\,cr}$	I_{cr}		
	Colour	$P_{T\,colour} =$	$I_{colour} =$	$P_{max\,Total} =$	
	Form	$P_{T\,form} =$	$I_{form} =$		
	Material	$P_{T\,material} =$	$I_{material} =$	$N_{FD} =$	
	Dimensioning	$P_{T\,dimensioning} =$	$I_{dimensioning} =$		

In accordance with the structure presented in Table 3.41., in order to determine the assessment indicators (on the basis of which the data will be interpreted), the **author proposed** the FTESE method application by completing the following steps:

1) Starting from the notation of the criteria in the assessment format (Table 3.38. or Table 3.39.), the appropriate field will be marked according to the extent to which the product meets the criterion, considering the 5 steps Likert scale.

2) It is identified according to Table 3.40. the product class and associated values for the I_D dimension importance indicator, following that they are noted in the first column of the assessment structure next to the indicators I_F, I_T, I_{Er}, I_S and I_{Es}.

3) Numerical values will be assigned to the marks from 1 to 5 and graded in the column C_* through the correspondent associated with each criterion (C_{c1}, C_{f1}, C_{m1}, etc.).

4) The maximum value of the dimension D_{max} is determined on the basis of relation (3.36), this representing the maximum value of a criterion multiplied by the number of relevant criteria.

$$D_{max} = c_D * C_{max} \quad (3.36)$$

where, c_D is the number of criteria applicable to the dimension and C_{max} represents the maximum value of a criterion.

Depending on each class, the maximum value of the dimension may differ, certain classes having criteria that cannot be assessed. Therefore, $D_{\max}$ can take values up to 20 (since C_* can take values up to a maximum of 5, except in the functional assessment where the criterion can have the value of 4/8/12/16/20, 4 being for total disagreement and 20 for total agreement), this representing the equivalent in equal ratios for the five assessment dimensions.

5) The weighted value of the criterion $\boldsymbol{P_*}$ will be calculated based on the relation (3.37), the values obtained will be noted in the assessment format for P_{c1}, P_{f1}, P_{m1}, etc.

$$P_* = \frac{C_*}{D_{\max}} * I_D \tag{3.37}$$

where, C_* represents the value of the criterion, $D_{\max}$ is the maximum value of the considered dimension and I_D represents the dimension importance.

6) The maximum weighted values are determined $\boldsymbol{P_{\max D}}$ for each dimension related to the features $P_{\max T}$, $P_{\max Er}$, $P_{\max S}$, $P_{\max Es}$, these representing for each dimension its maximum value P_*, the values thus determined being noted in the assessment structure.

$$P_{\max D} = \frac{C_{max}}{D_{\max}} * I_D \tag{3.38}$$

where, C_{max} represents the maximum value of a criterion, $D_{\max}$ is the maximum value of the considered dimension and I_D is the importance of the dimension.

7) Based on the relation (3.39) it is determined $\boldsymbol{P_{\max Total}}$, this representing the maximum total value corresponding to the weighted values of the criteria.

$$P_{\max Total} = \sum_{D=1}^{N} P_{\max D} = P_{\max T} + P_{\max Er} + P_{\max S} + P_{\max Es} \tag{3.39}$$

where, N represents the number of dimensions defined by the features, D is the considered dimension and $P_{\max D}$ is the maximum weighted value of the dimension.

8) The total weighted value of each feature $\boldsymbol{P_{T\,cr}}$ is determined based on relation (3.40).

$$P_{T\,cr} = \sum_{q=1}^{m} P_q \tag{3.40}$$

where, m is the number of dimensions applicable to the feature, q is the considered criterion and P_q is the weighted value of the feature.

9) Based on the relation of the values obtained following the application of the relation (3.40), the assessment indicator $\boldsymbol{I_{cr}}$ is calculated for each feature by applying the relation (3.41).

$$I_{cr} = \frac{P_{T\,cr}}{P_{\max Total} - P_{\max D_o}} \tag{3.41}$$

where, $P_{T\,cr}$ represents the total weighted value of a feature in question, $P_{\max Total}$ is the maximum total value corresponding to the weighted values of the criteria and $P_{\max D_o}$ represents the maximum weighted value of a dimension for which the feature in question cannot be assessed.

If all the features can be assessed for all dimensions, $P_{\max D_o}$ is zero, as the indicator has value only if a criterion cannot be applied. For example, if colour cannot be assessed aesthetically, the colour feature indicator is calculated by the relation (3.42).

$$I_{colour} = \frac{P_{T\,colour}}{P_{\max Total} - P_{\max Es}} \tag{3.42}$$

10) The total weighted values $\boldsymbol{P_D}$ will be determined based on relation (3.43) for each dimension related to features D.

$$P_D = \sum_{q=1}^{c_D} P_{Dq} \tag{3.43}$$

where, D is the considered dimension, c_D represents the number of criteria applicable to the dimension and q is the criterion considered for the dimension.

For each dimension, the relation (3.43) can be written as well as:

$$P_T = P_{c1} + P_{f1} + P_{m1} + P_{d1} \tag{3.44}$$

$$P_{Er} = P_{c2} + P_{f2} + P_{m2} + P_{d2} \tag{3.45}$$

$$P_S = P_{c3} + P_{f3} + P_{m3} + P_{d3} \tag{3.46}$$

$$P_{Es} = P_{c4} + P_{f4} + P_{m4} + P_{d4} \tag{3.47}$$

11) The total weighted value for the functional dimension $\boldsymbol{P_F}$ will be determined on the basis of the relation (3.48).

$$P_F = \frac{C_F}{D_{\max F}} * I_F \tag{3.48}$$

where, C_F represents the value of the functional criterion, $D_{\max F}$ is the maximum value of the functional dimension and I_F is the value of importance for functionality.

12) Finally, by summing the total weighted values of the dimensions, the value of the indicator $\boldsymbol{N_{FD}}$ will be determined by applying the relation (3.49), this representing the final assessment design score of the considered industrial product.

$$N_{FD} = \sum_{D=1}^{n} P_D = P_F + P_T + P_{Er} + P_S + P_{Es} \tag{3.49}$$

where, n represents the total number of dimensions, D is an indicator for a considered dimension, P_F is the total weighted value for the functional dimension, P_T is the total weighted value for the technical dimension, P_{Er} is the total weighted value for the ergonomic dimension, P_S is the total weighted value for the symbolism dimension and P_{Es} is the total weighted value for the aesthetic dimension.

Considering the maximum values in relation to those obtained for N_{FD} (which can take values up to 100) and I_{cr} (indicator that can have a maximum value of 1), the extent to which the product design corresponds to the proposed assessment standards is interpreted in the next phase.

3.3.2. Data analysis and indicator interpretation

One of the main advantages of the method is the possibility to apply it both in the individual assessment of a product and the comparative assessment. In the individual assessment, the interpretation of the data will done based on the N_{FD} indicator (that can take a maximum value of 100, this being meant to reflect the degree of innovation and reliability of the product, together with the quality level associated with it), the indicator C_F/E_F (consultative in this case) and representative indicators for features I_{colour}, I_{form}, $I_{material}$ and $I_{dimensioning}$, which will be interpreted based on Table 3.42. (according to the intervals established for I_{cr} in relation to the extent to which the feature fulfils its role).

Table 3.42. Structure of interpretation for features indicators, proposed by the author

Reference interval I_{cr}	Degree of fulfilment of the feature	Degree indicator
$I_{cr} \in [0.2, 0.4)$	The feature does not fulfil its role	-1
$I_{cr} \in [0.4, 0.6)$	The feature fulfils its role to a small extent	
$I_{cr} \in [0.6, 0.8)$	The feature relatively fulfils its role	0
$I_{cr} \in [0.8, 1)$	The feature fulfils its role to a large extent	+1
$I_{cr} = 1$	The feature totally fulfils its role	

In case I_{cr} has a value lower than 0.8, it is recommended to improve the product starting from the feature in question. This will be approached in the opposite direction of the assessment analysis, being considered primarily the dimensions with small values for the given feature, its relation to the market segment and context and reinterpretation of the feature in question depending on the importance of the correlation according to the pre-assessment phase. Also, in the phase for improving the product feature, it is recommended to take into account the way in which the other features can be affected, as shown in Fig. 3.14. according to Paper 7, taking into account the direction of influence and its nature (physical or perceptual).

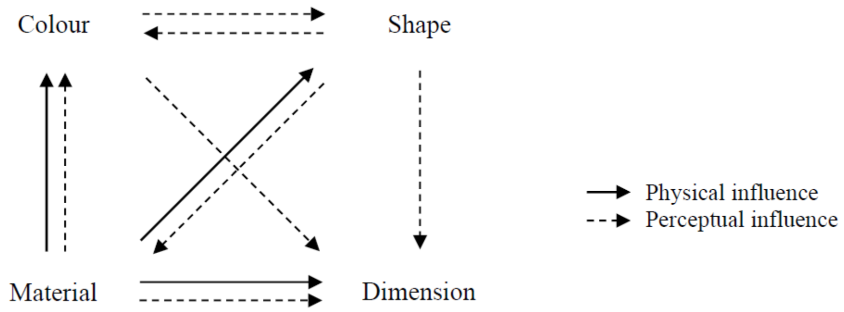


Fig. 3.14. Direction and type of influence between product features [Paper 7]

Regarding the comparative assessment, in the 'Interpretation sheet of the results in the comparative analysis', the results of the assessment for each product will be noted, being considered first of all the value for N_{FD} on the basis of which the selection of the optimal concept will be made. Along with the final assessment grade, the values obtained for the indicators associated with the functional assessment (C_F for standard assessment or E_F for extended assessment) and the representative indicators for features I_{colour}, I_{form}, $I_{material}$ and $I_{dimensioning}$ will be recorded with advisory role, these being relevant all the more as the comparative assessment is performed in the pre-production phase, having even the possibility of generating a new concept defined by the superior features that are reflected in the results in relation to the obtained values.

3.3.3. Results reporting

Based on the previously determined indicators, the **author proposed** the reporting of the assessment data in two versions depending on the degree of depth selected in the application of the method. Thus, for reporting the assessment data in the standard version, the relation (3.50) will be used, for this, functionality being considered according to the indicator C_F and for the extended version the relation (3.51) will be used, the functionality being considered in relation to the indicator E_F.

$$N_{FD}\ \underline{1} = \underline{2}\ (\text{C}\underline{3}):\ C_F = \underline{4}^{*},\ \text{c}(\underline{5}) = \underline{6},\ \text{f}(\underline{7}) = \underline{8},\ \text{m}(\underline{9}) = \underline{10},\ \text{d}(\underline{11}) = \underline{12} \tag{3.50}$$

$$N_{FD}\ \underline{1} = \underline{2}\ (\text{C}\underline{3}):\ E_F = \underline{4}^{**},\ \text{c}(\underline{5}) = \underline{6},\ \text{f}(\underline{7}) = \underline{8},\ \text{m}(\underline{9}) = \underline{10},\ \text{d}(\underline{11}) = \underline{12} \tag{3.51}$$

For the two relations, the data from the assessment will be completed as follows:

1 – brief product name;

2 – the value obtained for the indicator N_{FD} (defined by a maximum value of 100);

3 – class correspondent (it can be from 1 to 32, according to the Locarno classification);

4* – the value obtained for the functionality indicator C_F considered in the standard version (with values of 4, 8, 12, 16 or 20);

4** – the value obtained for the functionality indicator E_F considered in the extended version (can take values up to 100);

5 – degree of fulfilment of the colour feature (with values of -1, 0 or +1);

6 – the value obtained for the indicator I_{colour} (defined by a maximum value of 1);

7 – degree of fulfilment of the form feature (with values of -1, 0 or +1);

8 – the value obtained for the indicator I_{form} (defined by a maximum value of 1);

9 – degree of fulfilment of the material feature (with values of -1, 0 or +1);

10 – the value obtained for the indicator $I_{material}$ (defined by a maximum value of 1);

11 – degree of fulfilment of the dimensioning feature (with values of -1, 0 or +1);

12 – the value obtained for the indicator $I_{dimensioning}$ (defined by a maximum value of 1).

For features degree indicators (according to the associated positions in the reporting 5, 7, 9 and 11), the corresponding values are established in relation to the value of the associated indicators, according to the intervals previously presented in Table 3.42. The reporting of degree indicators aims to highlight the extent to which a feature may need improvement, for which the following three situations are found:

- The negative value of -1 is given according to the non-fulfilment threshold, for this, the feature needs improvement, situation in which $I_{cr} \in [0.2, 0.6)$ according to disagreement and total disagreement;

- The neutral value of 0 is given according to the relative fulfilment threshold, for this, the feature may require additional attention, in which case $I_{cr} \in [0.6, 0.8)$ according to the position of neutrality;

- The positive value of +1 is given according to the fulfilment threshold, for this, the feature does not need improvements (if even in this situation the improvement of the feature is further desired, the data can still be interpreted in relation to the value obtained for the indicator I_{cr}) situation in which $I_{cr} \in [0.8, 1.0]$ according to the agreement and total agreement.

It should be noted that, whether the assessment is applied individually or comparatively, data reporting will be performed using the same principle for each product (desirable aspect since comparative assessment is applicable for individual and not relative reporting), the differentiation being interpreted only for the degree of depth of the assessment according to the indicators C_F or E_F as is the case.

CHAPTER 4.

PRACTICAL CONTRIBUTIONS IN THE DESIGN ASSESSMENT OF INDUSTRIAL PRODUCTS

In order to test and validate the proposed method, with the support of a local producer of industrial goods, the assessment of three series of products found on the Romanian market specific to the 6th class Furniture was performed. Thus, a correlation study was performed in which the correspondence between the design indicators obtained from the assessment and the commercial success associated with the products was analysed, considering the sales volume corresponding to 2020 (data being provided by the manufacturing company, which is in this case also distributor and seller). For the three series of considered products, chairs, coffee tables and bedside tables, three related products were selected and, in their selection, in order to increase the relevance of the comparative assessment, the variations regarding their destination, the expected context of use, the target market segment and the price category were reduced as much as possible. All copyrights corresponding to the products (including their images presented in the thesis) belong to the manufacturing company and are used strictly for academic purposes. In the assessment it was intervened only from the perspective of effective testing according to the requirements of the method, including additional measurements and sensory analysis of the products. As the company willing to facilitate the study provided access to the product data sheets, the data of the target market segment, along with sales indicators, the name of the company will be kept confidential. In the presented thesis, the analysis of the products and the marking of the criteria for all nine products were presented in subchapter 6.1, and the results of the assessment being presented in the summary only for the first series of those evaluated. Thus, for series A products, Annex 19..21 contains the assessment format in the extended version and Annex 28 presents the interpretation sheet of the results corresponding to the comparative assessment. In addition, a pre-assessment form was presented in Annex 5, on the basis of which the assessment data corresponding to the products were interpreted.

4.3. RESULTS REPORTING

As the assessment of the products of the three series was performed in the extended version, the data reporting will be performed based on the relation (3.51) presented above, the functionality indicator considered being E_F and the class corresponding to all the products in this analysis being Class 6 Furniture. Thus, for series A products, the results of the application of the FTESE method were reported in relations (4.149)..(4.151). For the three products, the order generated by the final design assessment grade N_{FD} is also highlighted by the corresponding materials, P3A having the maximum value (this being the only product that actually reflects the type of component materials, namely wood and fabric) product P1A having intermediate value, and product P2A being defined by the lowest value, the latter two products being made of vinyl and metal, materials that, along with the associated volume, further disadvantage the P2A product.

N_{FD} P1A = 78.25 (C06): E_F = 83.33, c(0) = 0.66, f(+1) = 0.87, m(0) = 0.60, d(+1) = 0.93 (4.149)

N_{FD} P2A = 65.25 (C06): E_F = 67.33, c(+1) = 1.00, f(0) = 0.63, m(-1) = 0.47, d(+1) = 0.72 (4.150)

N_{FD} P3A = 84.75 (C06): E_F = 76.76, c(0) = 0.76, f(+1) = 0.89, m(+1) = 0.89, d(+1) = 0.94(4.151)

For series B products, the reporting of data was presented in relations (4.152)..(4.154), the values obtained for the indicator N_{FD} being reflected both in functionality and form, thus, the maximum value was obtained for the product P3B, the intermediate value is of the product P2B, and P1B having the minimum value within the series.

N_{FD} P1B = 66.25 (C06): E_F = 67.67, c(0) = 0.63, f(0) = 0.70, m(0) = 0.66, d(0) = 0.77 (4.152)

N_{FD} P2B = 75.25 (C06): E_F = 77.00, c(+1) = 0.80, f(0) = 0.76, m(0) = 0.66, d(0) = 0.71 (4.153)

N_{FD} P3B = 80.75 (C06): E_F = 81.00, c(+1) = 0.83, f(+1) = 0.84, m(0) = 0.77, d(+1) = 0.80(4.154)

For series C, the results were reported according to relations (4.155)..(4.157), the maximum value N_{FD} being identified for the P3C product, the intermediate value for P1C and the minimum value for P2C, these aspects being also highlighted by the dimensioning and the material of the products, the P2C product having plastic elements represented by metal and wood finishes.

N_{FD} P1C = 72.50 (C06): E_F = 76.33, c(0) = 0.66, f(0) = 0.73, m(0) = 0.66, d(0) = 0.73 (4.155)

N_{FD} P2C = 68.25 (C06): E_F = 67.67, c(+1) = 0.90, f(0) = 0.69, m(-1) = 0.57, d(0) = 0.71 (4.156)

N_{FD} P3C = 74.00 (C06): E_F = 76.00, c(0) = 0.79, f(0) = 0.69, m(0) = 0.66, d(0) = 0.73 (4.157)

Following the reporting of the data, for each considered series, additional analysis observations were presented in the annexes of the related series, being analysed the correspondence relation between N_{FD} indicator and secondary indicators considered E_F, c - I_{colour}, f - I_{form}, m - $I_{material}$ and d - $I_{dimensioning}$. Also, as will be seen in the next step, as the assessment was made for products already on the market, the secondary indicators will not be interpreted according to the degree of fulfilment, these being addressed numerically in the additional correlation study.

4.4. ANALYSIS AND CONCLUSIONS

The results of the assessments previously applied were recorded in the comparative assessment sheets in the corresponding annexes for each series (only Annex 28 for series A products is presented in the summary). Regarding data analysis, as the assessment was performed in the post-production phase, the features of the product will not be analysed considering recommendations for improvement (as is the case for pre-production assessment and selection of the optimal concept), however it will be determined whether there is a significant relation between the commercial success associated with the products defined as sales volume compared to a given period (the manufacturing company reported the estimated sales volume for 2020) and the values obtained for the indicators N_{FD} determined following the application of the FTESE assessment to the products concerned.

Table 4.49. Value of N_{FD} indicators related to sales volume

Series	Product	Value of N_{FD} indicator	Basic sales volume	Sales compared to the average of the category
Series A	P1A	78.25	2500	0.20
	P2A	65.25	3000	0.24
	P3A	84.75	7000	0.56
Series B	P1B	66.25	100	0.20
	P2B	75.25	200	0.40
	P3B	80.75	200	0.40
Series C	P1C	72.50	1000	0.35
	P2C	68.25	450	0.16
	P3C	74.00	1400	0.49

As can be seen, the basic sales volume is applicable comparatively only for the series in question (although all products correspond to the same class, they belong to different sub-classes for each series). Thus, in order to analyse the relation between the sales volume and the final design assessment grade, in order to reduce the numerical discrepancies between the series, an additional phase of data normalization was performed. As a result, the value of a sales indicator was determined by reporting its base value to the total value of the considered series, the results obtained being presented in the last column of Table 4.49., all values thus identified being in the range [0, 1] in direct relation to the success of the product in the series, according to the data provided by the manufacturing company. Considering the indicators thus presented in the previous table, in order to determine the degree of significance of the relationship between the value N_{FD} and sales volume relative to the category average, as the two data columns used in the study are considered to be continuous variables, a correlation analysis was performed using the Pearson method. For this, the determination and interpretation of correlation data was performed using the statistical analysis software program SPSS [184]. Thus, considering the degree of freedom N-2 (N being in this case 9) the associated value of 7 was obtained, the results being reported as follows $r(7) = 0.697$, $p = 0.037$. Based on the values obtained, the statistical relevance related to the value was deduced $p < 0.05$ and the degree of correlation of 0.697, which is a relatively high correlation between the value of design indicators and commercial success relative to sales volume. Also, considering the positive result, the direction of correlation was observed, being highlighted the fact that a high N_{FD} indicator is directly related to the sales volume of the products. Although the value of the previously obtained correlation is statistically relevant and defined by a relatively high degree of importance, as expected, it is not absolute (with a value of 1.00), in correspondence with the perfect correlation. In order to analyse in detail what could influence the effect between commercial success and the aspects associated with the product design, the values of the secondary indicators considered in the comparative analysis were also analysed (on the basis of which the final N_{FD} value was determined). Thus, the additional analysis of the correlation between the value associated with sales and functionality was performed together with the indicators of the four features.

For the next Pearson correlation analysis performed for the secondary indicators, the results obtained were reported as follows:

- Functionality: $r(7) = 0.380$, $p = 0.314 \rightarrow r < \pm 0.5$, $p > 0.05$
- Colour: $r(7) = -0.041$, $p = 0.916 \rightarrow r < \pm 0.5$, $p > 0.05$
- Form: $r(7) = 0.398$, $p = 0.289 \rightarrow r < \pm 0.5$, $p > 0.05$
- Material: $r(7) = 0.752$, $p = 0.019 \rightarrow r > \pm 0.5$, $p < 0.05$
- Dimensioning: $r(7) = 0.226$, $p = 0.559 \rightarrow r < \pm 0.5$, $p > 0.05$

Analysing the data thus obtained for the variables, the following aspects are recorded: functionality, colour, form and dimensioning are statistically inconclusive variables ($p > 0.05$), the material being the only conclusive variable and defined by a relevant degree of correlation, since $p = 0.019$ ($p < 0.05$), and the value obtained for the degree of correlation being relatively high, $r = 0.752$ ($r > \pm 0.5$), the direction is also positive. It is also observed that the correlation value obtained for the material is even higher compared to that related to the general assessment indicator N_{FD} for which $r = 0.697$ ($r > \pm 0.5$), although the difference is not very high, it is noticeable. Considering the results obtained for this study, we can thus admit the tendency of buyers to select mainly products defined by superior design, a general effect that is valid but not absolute. Regarding the relation to the elements subordinated to the design of the product, the data analysis interprets that, in the purchasing decision, only the impact of the material on the design is recognized, which would mean that, from the buyer's perspective, the material is thus seen as a dominant aspect. Moreover, relating the principle to the design dimensions, the material could be the only feature whose effect is made aware from the perspective of the set of associated dimensions, the buyer could thus consider the technical and ergonomic implications through the effect on comfort, symbolism and even the aesthetic degree. For the other aspects of the analysis, making additional observations in relation to the value of the degree of correlation, although they are much less important by comparison, the relation of secondary rank related to the impact of functionality and form on the product is observed, followed by dimensioning. Of all the features considered, one can observe the atypical result obtained for the colour, for this even the direction being different (the result having a negative meaning), which could imply that, mainly, the buyer could be to a very small extent aware of the effect of colour on product design. Referring to this feature in terms of design dimensions, there is the possibility that the effect is mainly due to symbolism associations and implicitly personal preferences over the colour palette and less how the colour of the product would influence the degree of maintenance, the psychological effect and the impact on the context of use or even the degree of harmony associated with the chromatic complexity.

CHAPTER 5.

PRACTICAL DEVELOPMENTS IN THE DESIGN ASSESSMENT OF INDUSTRIAL PRODUCTS

5.1. IMPLEMENTATION AND PRESENTATION OF THE PLATFORM

Starting from the purpose of reducing the degree of difficulty associated with the application of the method, the **author proposed** the development of a software application that automatically calculates the values of the assessment indicators. As we want as much accessibility as possible to the application, the calculation algorithm has been integrated into a bilingual web platform (available for Romanian and English) that can be accessed from the website www.ftese.com[2]. In order to avoid the risk of self-plagiarism and data indexing, the platform is currently available based on authentication, the access password being: ftese2021

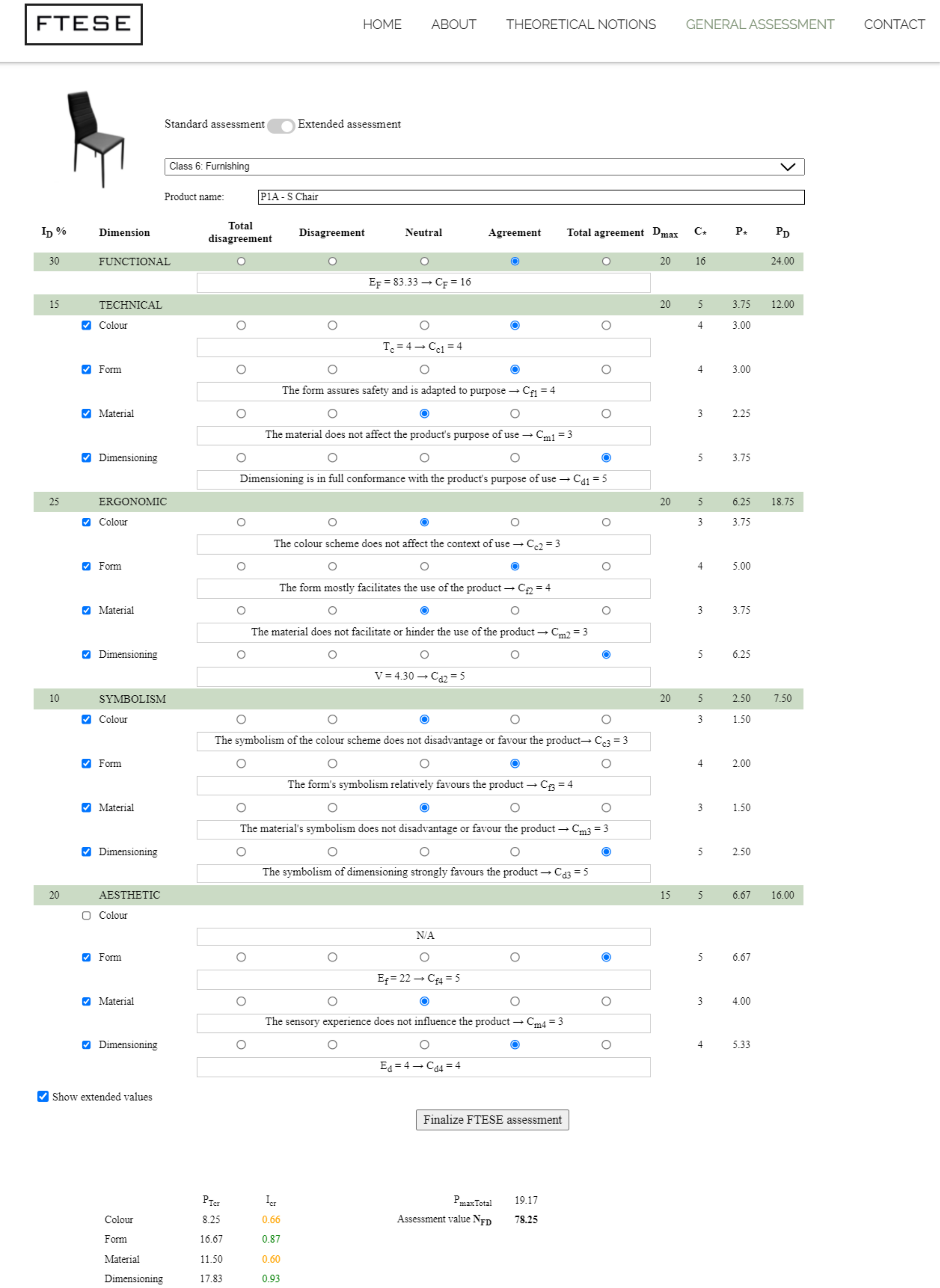
[2] Ownership of the platform's content, including text, graphics or other representative details regarding the concept or calculation algorithm belongs to the author

The assessment of the platform starts from the consultation of the application phases in the case of the individual assessment and the completion of the corresponding sheet. With regard to the application procedure, as opposed to the theoretical version of the method, in order to carry out the individual assessment, the **application steps are considerably reduced**, since less information in the description is needed for the graphical representation and access to data is much easier to be spotted (**direct connections to the desired sections** are presented). Also, another aspect that has an impact in reducing the volume of data is regarding the effective application and determination of assessment indicators, after noting the criteria the **calculation steps are excluded** (including the step of identifying the importance values of the dimensions according to the class and the completion of the indicator determination structure), the **results being thus determined automatically**, which also implies **much lower risks of misinterpretation of the data**. Starting from the aspects presented above for the individual assessment, in the case of the comparative assessment, there are minor differences of applicability between the two approaches, the comparative assessment starting from the completion of the corresponding pre-assessment sheet (accessible and editable within the platform, applied in this case for at least two considered products) and the determination and reporting of the data is carried out on the same principle described in the individual assessment without the need to go through separate phases. Following the interpretation of the data, in the final stage of application, the graphical version of the reporting of the results was presented, and to facilitate even more the interpretation of the data, the **numerical values of the features indicators were adapted in the form of colour codes**, red being the equivalent threshold of $I_{cr} \in [0.2, 0.6)$ associated with the negative degree of -1, yellow is the equivalent of the threshold of $I_{cr} \in [0.6, 0.8)$ associated with the neutral degree of 0, and green is the equivalent threshold of $I_{cr} \in [0.8, 1.0]$ associated with the positive degree of +1.

Regarding the actual assessment format (accessible from the general assessment page), if it is desired to correlate the method with the theoretical version, there is the **possibility to display the calculation indicators** (if the corresponding box is marked at the end of the assessment), being presented the values of the indicators on the basis of which the data are determined I_D, D_{max}, C_*, P_* and P_D, and upon completion of the assessment being displayed also P_{Tcr} and $P_{\max Total}$, along with the indicators needed in interpreting the data I_{cr} and N_{FD}, the latter being the only indicators for which the final values are displayed without direct correlation with the theoretical version. In the general assessment, in the situation where a criterion cannot be interpreted according to the specifics of the evaluated product, **for each dimension there is the possibility of individual exclusion of features** by simply deselecting the criterion marking (effect valid for all features and related dimensions considered, however marking all dimensions as a whole is required). Also, within the general assessment format, the **transition from the standard assessment to the extended assessment can be made**. For the extended assessment, all the principles described above are valid, the difference is the removal of antagonistic attributes and instead displaying editable fields of observations for each considered criterion (since this time the criteria are noted according to the results obtained in applying the additional notions). Also, in this case, to carry out the extended assessment based on additional studies, in the section of theoretical notions, along with the description of the steps of criteria interpretation is the presentation of **sub-methods for which values are also determined automatically**, the algorithm being implemented for seven sub-methods, namely: functional analysis, familiarity - novelty, formal honesty - playfulness, ergonomic dimensioning analysis, ergonomic colour analysis, aesthetic form analysis and aesthetic dimensioning analysis. Thus, for each of them, by simply selecting the degree of fulfilment or completion in the editable fields of value data according to the assessed product, the value of the indicators of the criteria in question is displayed together with the relevant numerical equivalent in the general assessment (information that facilitates the correlation of the application with the theoretical version but without making the application in the platform informationally aggravated).

5.2. FTESE PLATFORM TESTING

In order to test the developed FTESE platform, the first product from the previous selection P1A was considered as an example, in the thesis being presented for the testing phase both the general format and the sub-methods that required the integration of an algorithm, the obtained results being the same as those in the theoretical version.



FTESE

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Standard assessment / Extended assessment

Class 6: Furnishing

Product name: P1A - S Chair

I_D %	Dimension	Total disagreement	Disagreement	Neutral	Agreement	Total agreement	D_{max}	C_*	P_*	P_D
30	FUNCTIONAL	○	○	○	●	○	20	16		24.00
		$E_F = 83.33 \rightarrow C_F = 16$								
15	TECHNICAL						20	5	3.75	12.00
	☑ Colour	○	○	○	●	○		4	3.00	
		$T_c = 4 \rightarrow C_{c1} = 4$								
	☑ Form	○	○	○	●	○		4	3.00	
		The form assures safety and is adapted to purpose → $C_{f1} = 4$								
	☑ Material	○	○	●	○	○		3	2.25	
		The material does not affect the product's purpose of use → $C_{m1} = 3$								
	☑ Dimensioning	○	○	○	○	●		5	3.75	
		Dimensioning is in full conformance with the product's purpose of use → $C_{d1} = 5$								
25	ERGONOMIC						20	5	6.25	18.75
	☑ Colour	○	○	●	○	○		3	3.75	
		The colour scheme does not affect the context of use → $C_{c2} = 3$								
	☑ Form	○	○	○	●	○		4	5.00	
		The form mostly facilitates the use of the product → $C_{f2} = 4$								
	☑ Material	○	○	●	○	○		3	3.75	
		The material does not facilitate or hinder the use of the product → $C_{m2} = 3$								
	☑ Dimensioning	○	○	○	○	●		5	6.25	
		$V = 4.30 \rightarrow C_{d2} = 5$								
10	SYMBOLISM						20	5	2.50	7.50
	☑ Colour	○	○	●	○	○		3	1.50	
		The symbolism of the colour scheme does not disadvantage or favour the product→ $C_{c3} = 3$								
	☑ Form	○	○	○	●	○		4	2.00	
		The form's symbolism relatively favours the product → $C_{f3} = 4$								
	☑ Material	○	○	●	○	○		3	1.50	
		The material's symbolism does not disadvantage or favour the product → $C_{m3} = 3$								
	☑ Dimensioning	○	○	○	○	●		5	2.50	
		The symbolism of dimensioning strongly favours the product → $C_{d3} = 5$								
20	AESTHETIC						15	5	6.67	16.00
	☐ Colour									
		N/A								
	☑ Form	○	○	○	○	●		5	6.67	
		$E_f = 22 \rightarrow C_{f4} = 5$								
	☑ Material	○	○	●	○	○		3	4.00	
		The sensory experience does not influence the product → $C_{m4} = 3$								
	☑ Dimensioning	○	○	○	●	○		4	5.33	
		$E_d = 4 \rightarrow C_{d4} = 4$								

☑ Show extended values

Finalize FTESE assessment

	P_{Tcr}	I_{cr}
Colour	8.25	0.66
Form	16.67	0.87
Material	11.50	0.60
Dimensioning	17.83	0.93

$P_{maxTotal}$ 19.17

Assessment value N_{FD} **78.25**

Fig. 5.9. Presentation of the general assessment of the P1A product within the FTESE platform

After determining the values of the evaluation criteria, starting from the selection of the corresponding class and completing the product identification data, the general assessment format FTESE (in the extended version) was noted based on the values previously determined in the sub-methods next to the assigned values (in relation to the theoretical notions). Thus, each criterion was approached according to the specific situation by marking the position corresponding to the degree of fulfilment and completing the fields of observations associated with the grading. For the colour aesthetic assessment for the exemplified product, as the analysis could not be performed, the corresponding criterion was unmarked from the assessment format, the N/A message being displayed in the comments field. As a result, the criterion will be automatically excluded from the assessment without affecting the features setting values. For the considered example, it was presented in Fig. 5.9. the assessment format of the P1A product in the version in which it was chosen to display the calculation values (since the correlation with the theoretical version of the method was desired). In the data interpretation phase, considering the features values, based on the results obtained and using the graphical principle described in the calculation phase section of the platform, the values I_{cr} were interpreted as follows:

- I_{colour} = 0.66 (yellow) → the value of the fulfilment threshold is 0
- I_{form} = 0.87 (green) → the value of the fulfilment threshold is +1
- $I_{material}$ = 0.60 (yellow) → the value of the fulfilment threshold is 0
- $I_{dimensioning}$ = 0.93 (green) → the value of the fulfilment threshold is +1

In the last phase of the method application, considering the previous analysis of the features indicators together with the obtained value of 78.25 for the indicator N_{FD} and the value of 83.33 for E_F indicator (as it is visible in the first scoring field of the format, according to the functional assessment) the results were reported as follows:

N_{FD} P1A = 78.25 (C06): E_F = 83.33, c(0) = 0.66, f(+1) = 0.87, m(0) = 0.60, d(+1) = 0.93 (5.1)

As can be observed, the reporting of results according to relation (5.1) are the same as the ones obtained previously in relation (4.149), therefore it can be considered validated the testing stage of the platform. Moreover, between the two presented versions of application of the method (the theoretical one and the one within the platform) the major difference consisted in the time allocated and of course the effort required in obtaining the results. At the current time, it can be considered that the platform is functional, being usable in both the extended and the standard version, with individual and comparative applicability of the assessment. However, it is desired the constant improvement of the FTESE platform and the facilitation of the application as much as possible, therefore for the next version it is desired to correlate the data in as much detail as possible and to have the possibility to export the information in .pdf format for both assessment sheets, sub-methods and general assessment formats. An improved version for the mobile version is also desired as the current display format for automatic calculation methods is relatively difficult on devices with major differences in resolution. Another aspect taken into account in further developments of the platform is the presentation of a relevant additional section in case the assessment is applied in the pre-production phase, in which recommendations are presented to improve the features considering the influence relations between them (as previously presented in the theoretical version in Fig. 3.14.). Thus, all these aspects contribute in product design in creating a complex analysis that involves at the same time a minimum effort in implementation, the platform being meant to support as much as possible the performing of a superior assessment from a qualitative perspective.

CONCLUSIONS

C1. GENERAL CONCLUSIONS

This paper started from the concept of generating in the assessment of industrial design a structure of ToE nature (theory of everything), which led to the proposal of new approaches in design assessment, also identifying multiple other aspects that require additional attention (presented in section C.3.), however as will be seen, they are mainly related to certain niche elements or particular details. Moreover, for all the resulting criteria, perspectives for their analysis and scoring were presented (using the 5-step Likert scale), the sub-methods developed being considered especially in situations where they proved to be necessary in scoring the criterion, as is the case, for example, in the analysis of the relation formal honesty - playfulness, for which a form adapted absolutely to purpose is not imposed but it delimits the point at which the decorative variations can disadvantage the product much more than it could bring a real contribution. The intervals thus established for the values associated with the total agreement allow a certain form of flexibility, a situation which is also applicable to the other criteria. Even with the possible variations associated with the degree of fulfilment, clearly delimited grading principles have been established for all these. As a result, according to the main objective of the paper, the proposed method is a framework for interpreting the factors influencing design, taking into account the extent to which they can impact even in detail the final form of the product. Regarding the fulfilment of the other proposed objectives, based on the analysis of the current stage, the optimal specificity of the assessment method was identified together with the set of factors that can influence the design of industrial products, based on which the assessment criteria were structured (according to objectives *O.1.* and *O.2.*). In case of applicability of the method, it can be used both in the pre-production and selection phase of the optimal concept and post-production by identifying superior products, the method can also be applied individually for all types of industrial products based on Locarno classification (according to objective *O.3.*), the most objective reporting of the criteria being made based on the pre-assessment phase, taking into account the relation of influence between product features and user specificity (according to objective *O.4.*). Depending on the degree of depth desired in the assessment, there are two versions (according to objectives *O.5.* and *O.6.*), a standard version by relating the criteria to antagonistic attributes and an extended structure based on additional studies, within which sub-methods have been developed for the newly generated criteria (according to objective *O.7.*), for both versions the results can be interpreted both based on the final assessment indicator and comparatively for features (according to objectives *O.8.* and *O.9.*). Considering the method thus proposed, an analysis study was performed between the values obtained from the application of the method and consumer preferences (according to objective *O.10.*) identifying a relatively high (but not absolute) correlation between the two indicators. Also based on the study, the presented web platform was developed and tested (according to objective *O.11.*), the results obtained from the application of the method in the theoretical version being the same as those resulting from the FTESE application. Although, through the platform, the assessment can be done in a fast way, it is essential for each evaluated criterion to be well documented, the degree of involvement in carrying out the assessment strongly influencing the quality of the results and implicitly the quality of the products. In view of the aspects described, it can thus be concluded that both the main objective and all other associated objectives have been met.

C2. ORIGINAL CONTRIBUTIONS

Throughout the thesis, the following novelty elements were presented, structured in five sections, starting from the analysis studies and the theoretical perspectives of approaching the concepts and based on them the delimitation of the assessment concepts. Also, in approaching the assessment of the 17 criteria generated, new perspectives for their assessment were presented, along with the related sub-methods, all of which ultimately contribute to the general elements of novelty corresponding to the FTESE method for assessing industrial design. The considered sections, together with the related novelty elements being presented as follows:

- Analysis studies: Comparative analysis of hybrid design assessment methods, together with the corresponding criteria, based on which the relevant impact elements in the design assessment were identified (1.2. and 1.3.); Analysis of the relation between quality and design, identifying the elements associated with quality in relation to the assessment dimensions (2.1.2); Analysis of the relation between the features of the product, considering the type and direction of their influence, relevant in the situation where it is desired to improve a feature following the interpretation of the assessment results (3.3.1.);

▪ Theoretical perspectives to approach the concepts: Proposal to classify the current assessment methods based on five categories, exemplified and presented together with the related sub-categories (1.1.); Structure to differentiate the importance of assessment dimensions in relation to the corresponding product class (beginning of Chapter 3); Structure of hierarchy of interdependence relations between product features and user specificity, the features being thus interpreted according to the degree of correlation with the elements of the market segment and the associated use context (3.1.).

▪ New perspectives for assessing and grading of criteria: Technical assessment of colour, based on two analysis perspectives considering the specificity of the colour scheme in relation to the degree of conformity to purpose and the specificity of technical colour systems, along with the classification proposal based on three specific situations in which colour coding systems are found (3.2.2.1.); Ergonomic assessment of colour, being proposed a new approach for colour in relation to the degree of its adaptation to the context of use, considering the chromatic associations and the generated sensation (3.2.3.1.); Ergonomic assessment of form, based on a format of interpretation of the formal elements of the product with which the user comes into contact, considering the degree of dependence of the activity on the mobility of the product in relation to the level of support in the product-user relations (3.2.3.2.); Ergonomic assessment of dimensioning, for which a relation of interpretation of dimensioning variations between the dimensions of the product and the anthropometric dimensions associated with the user is proposed (3.2.3.4.); Aesthetic colour assessment, considering the average between the degree of colour compatibility considered as selective harmony and the optimal degree of surface coverage, considered as quantitative harmony (3.2.5.1.).

▪ Sub-methods developed: Development of a functional assessment format, interpreted on the basis of the ranking of five sections together with the criteria associated with the three levels of reporting for each section, for the functional assessment thus proposing a series of 15 corresponding sub-criteria (3.2.1.1.); Development of an approach to assessing the relation familiarity - novelty, considering the neutrality of the relation, along with reporting to the maximum value for both sections of familiarity and novelty (3.2.1.2.); Development of an approach to assess the relation between formal honesty and playfulness, analysing the extent to which playfulness can affect formal honesty (3.2.1.3.); Development of a method for determining the degree of chromatic harmony associated with the product in relation to the proportion of coverage of an area, on the basis of which the optimal degree of coverage of surfaces from an aesthetic point of view of colour is determined (3.2.5.1.); Development of a technique for scoring the assessment of the form of the product from an aesthetic perspective, taking into account the symmetry, the degree of fluidity of the form, balance, stability and complex relations of harmony associated with the form (3.2.5.2.); Development of a technique for grading aesthetic dimensioning, based on two categories, taking into account the principles of proportionality and the relations between the proportionality of the product elements and structural coherence (3.2.5.4.).

▪ General elements of novelty: Proposing a design assessment framework applicable both on the basis of antagonistic attributes and additional studies considering the same criterion structure (3.2); Development of a format for interpreting data following the grading of criteria, taking into account the possibility of comparative assessment of features even in the situation where a feature cannot be considered from the perspective of a dimension (3.3.1.); Proposal of a structure for interpreting the assessment results together with the numerical analysis of the features indicators. Establishing the threshold from which they need improvement, the structure of relative influence of the features was presented (3.3.2.); Proposal of a format for reporting the data resulting from the application of the assessment, highlighting the effect of design indicators on the considered product. In the format thus proposed, the degree of depth of the assessment is differentiated, considering, as the case may be, the functionality indicator C_F for the standard version or E_F for the extended version (3.3.3.); Study for identifying the correlation elements between the design assessment indicators (according to the proposed method) and the commercial success considering already existing products on the Romanian market (Chapter 4). Development of a web platform for the application of the FTESE method, following the grading of the criteria, the assessment parameters are automatically determined for both the general format and the proposed sub-methods (Chapter 5).

C3. PERSPECTIVES FOR FURTHER DEVELOPMENT

A series of concepts were identified regarding the assessment of the design of industrial products for which the potential of further studies was identified. Starting from the ergonomic analysis of the colour, it was found the possibility of an additional study to identify the existence of favourable correlations between the physiological effect generated by the colour scheme and the product typology. Within the ergonomic analysis of the dimensioning, it was recommended to report to anthropometric standards as close as possible ethnically to the cultural area to which the product is dedicated, as there is no frame of reference for measuring the human body in Romania. This presents the possibility of conducting a national analysis considering ethnic variations, gender and age, however it is worth mentioning in this case, that a study of this magnitude is very difficult to perform. In the first phase, a variant would be to approach only certain restricted aspects and the comparative analysis toward other anthropometry studies related to Caucasians, as there is the possibility that the initial proposed study may prove to be even redundant if the dimensional variations are relatively imperceptible. In assessing the significance, the potential of studies at national level was also identified, considering the associations of cultural symbolism regarding colour or material, analysing the historical and social influences and how they may vary in relation to the specifics of the user. As mentioned, we start from the premise that the level of experience of the evaluator is correlated with the objectivity of the assessment process and implicitly the quality of the results. Thus, a study is considered in which, for the same product series, the method proposed by both experienced and inexperienced evaluators is applied, analysing the extent to which there are noticeable differences in the rating of relevant criteria and thus identifying accordingly what could be improved in the presentation of concepts to help students in the field, for example, to assimilate notions regarding design assessment. The broadest perspective for further development is on the method itself and its application. For the case study presented before, the assessment was performed in the post-production phase (according to the degree of access allowed by the manufacturing company willing to accept the study) but the maximum potential of the method could be highlighted by application in the pre-production phase and selecting the optimal concept, in this case the commercial success considered in the correlation analysis would not only relate to the products themselves. On the long run, applying the method in case when it is considered the improvement of the products’ weaknesses, the correlation would be related to the overall success of the company, in which case the major impediment would be reflected in the fact that the analysis of such indicators would involve a long time to observe the effects. However, based on the study, the method was validated in both comparative analysis and implicitly individual and it aims to represent in the assessment of industrial product design a systematic structure of analysis, numerically interpretable, which takes into account the differential application of the product typology and its intended destination of use along with the most objective reporting to the user's specifics. Finally, in order to facilitate as much as possible the application of the proposed method, it is desired the continuous development of the FTESE platform, for future versions constantly taking into account both the quality of the application experience and the quality of the method itself.

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Note: The author 's publications are listed in Annex 33.

ANNEX 5. PRE-ASSESSMENT SHEET IN THE COMPARATIVE ANALYSIS – SERIES A

Class/Category: Class 6. Furnishing – Chairs Series A

Destination of use description: *The chairs considered in the A series are intended for the living room, they are expected to be used both for meal serving and for secondary activities, the general purpose being to provide comfort for the human body in resting state.*

A. MARKET SEGMENT

Age: Adults
Gender: General approach
Educational level: General approach
Income: Small and medium
Culture: Is considered the Romanian market

B. PRODUCT CHARACTERISTICS

	**P1A - Chair S** (≈ 55 USD)	
	Chromatic scheme – monochrome product, black colour Upholstery material – imitation leather (vinyl) Frame material – vinyl-coated metal Product weight – 5 kg Supported weight – 110 kg	Total product width – 44 cm Total product depth – 54 cm Total product height – 96 cm Sitting height – 46 cm Sitting width – min 32 cm, max 44 cm Sitting depth – 40 cm Backrest width – min 30 cm, max 40 cm Legs width – 2 cm
	**P2A - Chair E** ((≈ 62 USD)	
	Chromatic scheme – monochrome product, dark cappuccino upholstery colour, walnut finish legs colour Upholstery material – imitation leather (vinyl) Legs material – painted metal Product weight – 10 kg Supported weight – 150 kg	Total product width – 48 cm Total product depth – 44 cm Total product height – 104 cm Sitting height – 46 cm Sitting width – min 37 cm, max 48 cm Sitting depth – 39 cm Backrest width – 37 cm Legs width – 4 cm
	**P3A - Chair A** ((≈ 70 USD)	
	Chromatic scheme – grey-beige upholstery colour, cream-white finish legs colour Upholstery material – fabric Frame material – painted wood Product weight – 10 kg Supported weight – 100 kg	Total product width – 47 cm Total product depth – 58 cm Total product height – 98 cm Sitting height – 46 cm Sitting width – min 38 cm, max 47 cm Sitting depth – 40 cm Backrest width – min 32 cm, max 36 cm Legs width – 3.5 cm

C. CONTEXT AND HISTORICAL-COMPETITIVE ANALYSIS

All products of series A are part of class 6 Furnishing and subclass 100526 Chairs. In the first part of 2021 (considered in this analysis) the price of products is in the range [55,90], the average price being 63 USD.

Observations: In the competitive analysis, a series of 10 products in the same category was considered, being found for product weight the minimum weight of 1.70 kg, an average weight of 5.04 kg and a maximum weight of 8.00 kg, for the maximum supported weight by the product the following were found: the minimum value is 80 kg, the average value is 121.50 kg and the maximum value is 150 kg.

ANNEX 19. EXTENDED ASSESSMENT FORMAT OF PRODUCT P1A

Class: Class 6. Furnishing
Product name: P1A - Chair S

Dimension	Total disagreement	Disagreement	Neutral	Agreement	Total agreement
FUNCTIONAL	○	○	○	◉	○
			E_F = 83.33 → C_F = 16		
TECHNICAL					
Colour	○	○	○	◉	○
			T_c = 4 → C_{c1} = 4		
Form	○	○	○	◉	○
			The form assures safety and is adapted to purpose → $C_{f1} = 4$		
Material	○	○	◉	○	○
			The material does not affect the product's purpose of use → $C_{m1} = 3$		
Dimensioning	○	○	○	○	◉
			Dimensioning is in full conformance with the product's purpose of use → $C_{d1} = 5$		
ERGONOMIC					
Colour	○	○	◉	○	○
			The colour scheme does not affect the context of use → $C_{c2} = 3$		
Form	○	○	○	◉	○
			The form mostly facilitates the use of the product → $C_{f2} = 4$		
Material	○	○	◉	○	○
			The material does not facilitate or hinder the use of the product → $C_{m2} = 3$		
Dimensioning	○	○	○	○	◉
			V = 4.30 → C_{d2} = 5		
SYMBOLISM					
Colour	○	○	◉	○	○
			The symbolism of the colour scheme does not disadvantage or favour the product → $C_{c3} = 3$		
Form	○	○	○	◉	○
			The form's symbolism relatively favours the product → $C_{f3} = 4$		
Material	○	○	◉	○	○
			The material's symbolism does not disadvantage or favour the product → $C_{m3} = 3$		
Dimensioning	○	○	○	○	◉
			The symbolism of dimensioning strongly favours the product → $C_{d3} = 5$		
AESTHETIC					
Colour	○	○	○	○	○
			N/A		
Form	○	○	○	○	◉
			E_f = 22 → C_{f4} = 5		
Material	○	○	◉	○	○
			The sensory experience does not disadvantage or favour the product → $C_{m4} = 3$		
Dimensioning	○	○	○	◉	○
			E_d = 4 → C_{d4} = 4		

ANNEX 20. EXTENDED ASSESSMENT FORMAT OF PRODUCT P2A

Class: Class 6. Furnishing
Product name: P2A - Chair E

Dimension	Total disagreement	Disagreement	Neutral	Agreement	Total agreement
FUNCTIONAL	○	○	◉	○	○
	E_F = 67.33 → C_F = 12				
TECHNICAL					
Colour	○	○	○	○	◉
	T_c = 5 → C_{c1} = 5				
Form	○	○	◉	○	○
	The form is mostly adapted to purpose → C_{f1} = 3				
Material	○	◉	○	○	○
	The material is mostly unsuitable for the product's purpose of use → C_{m1} = 2				
Dimensioning	○	○	◉	○	○
	Dimensioning is mostly adapted to purpose → C_{d1} = 3				
ERGONOMIC					
Colour	○	○	○	○	◉
	The colour scheme is in full accordance with the context of use → C_{c2} = 5				
Form	○	○	◉	○	○
	The form does not facilitate or hinder the use the product → C_{f2} = 3				
Material	○	◉	○	○	○
	The material mostly hinders the use the product → C_{m2} = 2				
Dimensioning	○	○	○	◉	○
	V = 7.63 → C_{d2} = 4				
SYMBOLISM					
Colour	○	○	○	○	◉
	The symbolism of the colour scheme strongly favours the product → C_{c3} = 5				
Form	○	○	○	◉	○
	The form's symbolism relatively favours the product → C_{f3} = 4				
Material	○	◉	○	○	○
	The material's symbolism relatively disadvantages the product → C_{m3} = 2				
Dimensioning	○	○	○	○	◉
	The symbolism of dimensioning strongly favours the product → C_{d3} = 5				
AESTHETIC					
Colour	○	○	○	○	○
	N/A				
Form	○	○	◉	○	○
	E_f = 13 → C_{f4} = 3				
Material	○	○	◉	○	○
	The sensory experience does not disadvantage or favour the product → C_{m4} = 3				
Dimensioning	○	○	◉	○	○
	E_d = 2.5 → C_{d4} = 3				

ANNEX 21. EXTENDED ASSESSMENT FORMAT OF PRODUCT P3A

Class: Class 6. Furnishing
Product name: P3A - Chair A

<table>
<tr><th>Dimension</th><th>Total disagreement</th><th>Disagreement</th><th>Neutral</th><th>Agreement</th><th>Total agreement</th></tr>
<tr><td rowspan="2">FUNCTIONAL</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">E_F = 76.67 → C_F = 16</td></tr>
<tr><td colspan="6">TECHNICAL</td></tr>
<tr><td rowspan="2">Colour</td><td>○</td><td>○</td><td>◉</td><td>○</td><td>○</td></tr>
<tr><td colspan="5">T_c = 3 → C_{c1} = 3</td></tr>
<tr><td rowspan="2">Form</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">The form assures safety and is adapted to purpose → $C_{f1} = 4$</td></tr>
<tr><td rowspan="2">Material</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">The material is mostly suitable for the product's purpose of use → $C_{m1} = 4$</td></tr>
<tr><td rowspan="2">Dimensioning</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">Dimensioning is in full conformance with the product's purpose of use → $C_{d1} = 5$</td></tr>
<tr><td colspan="6">ERGONOMIC</td></tr>
<tr><td rowspan="2">Colour</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">The colour scheme corresponds to the context of use → $C_{c2} = 4$</td></tr>
<tr><td rowspan="2">Form</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">The form mostly facilitates the use of the product → $C_{f2} = 4$</td></tr>
<tr><td rowspan="2">Material</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">The material mostly facilitates the use of the product → $C_{m2} = 4$</td></tr>
<tr><td rowspan="2">Dimensioning</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">V = 3.55 → C_{d2} = 5</td></tr>
<tr><td colspan="6">SYMBOLISM</td></tr>
<tr><td rowspan="2">Colour</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">The symbolism of the colour scheme relatively favours the product → $C_{c3} = 4$</td></tr>
<tr><td rowspan="2">Form</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">The form's symbolism strongly favours the product → $C_{f3} = 5$</td></tr>
<tr><td rowspan="2">Material</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">The material's symbolism strongly favours the product → $C_{m3} = 5$</td></tr>
<tr><td rowspan="2">Dimensioning</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">The symbolism of dimensioning strongly favours the product → $C_{d3} = 5$</td></tr>
<tr><td colspan="6">AESTHETIC</td></tr>
<tr><td rowspan="2">Colour</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">E_c = 4 → C_{c4} = 4</td></tr>
<tr><td rowspan="2">Form</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">E_f = 23 → C_{f4} = 5</td></tr>
<tr><td rowspan="2">Material</td><td>○</td><td>○</td><td>○</td><td>○</td><td>◉</td></tr>
<tr><td colspan="5">The sensory experience strongly favours the product → $C_{m4} = 5$</td></tr>
<tr><td rowspan="2">Dimensioning</td><td>○</td><td>○</td><td>○</td><td>◉</td><td>○</td></tr>
<tr><td colspan="5">E_d = 4 → C_{d4} = 4</td></tr>
</table>

ANNEX 28. RESULTS INTERPRETATION SHEET – SERIES A

Class 6 - Furnishing		
Product name: **P1A - Chair S**	Product name: **P2A - Chair E**	Product name: **P3A - Chair A**
		
$\boldsymbol{N_{FD}}$ **= 78.25**	$\boldsymbol{N_{FD}}$ **= 65.25**	$\boldsymbol{N_{FD}}$ **= 84.75**
E_F = 83.33	E_F = 67.33	E_F = 76.76
I_{colour} = 0.66	I_{colour} = 1.00	I_{colour} = 0.76
I_{form} = 0.87	I_{form} = 0.63	I_{form} = 0.89
$I_{material}$ = 0.60	$I_{material}$ = 0.47	$I_{material}$ = 0.89
$I_{dimensioning}$ = 0.93	$I_{dimensioning}$ = 0.72	$I_{dimensioning}$ = 0.94

Data reporting:

N_{FD} P1A = 78.25 (C06): E_F = 83.33, c(0) = 0.66, f(+1) = 0.87, m(0) = 0.60, d(+1) = 0.93

N_{FD} P2A = 65.25 (C06): E_F = 67.33, c(+1) = 1.00, f(0) = 0.63, m(-1) = 0.47, d(+1) = 0.72

N_{FD} P3A = 84.75 (C06): E_F = 76.76, c(0) = 0.76, f(+1) = 0.89, m(+1) = 0.89, d(+1) = 0.94

Observations: For the three products from series A considered in the analysis, the maximum value of the N_{FD} indicator was 84.75 for the P3A product, the intermediate value was 78.25 for the P1A product and the minimum value was 65.25 for the P2A. As can be seen, the values corresponding to the E_F functionality indicator are not directly related to the N_{FD} indicators associated with the products, which implies a relatively large variation in the degree of fulfilment of the features. Thus, the P1A product is defined by high values for form and dimensioning and medium values for colour and material. In the case of the P2A product, the biggest discrepancy is observed, the form and dimensioning indicators having average values, the colour being defined by the maximum indicator, compared to the material that has a very low value. For the P3A product, although the degree of functionality is not the highest (compared to the other two products), the values of the features indicators are very high.

ANNEX 33. LIST OF PUBLICATIONS

[**Paper 1**] *Dumitrescu A., Ulmeanu M. E. and **Crăciun A. E.**,* “Technotope: A Framework for Designing Interiors”, Acta Technica Napocensis: Civil Engineering & Architecture, **vol. 62**, no. 1, pp. 60-71, 2019. ISSN 2344-4711

[**Paper 2**] *Dumitrescu A. and **Crăciun A. E.**,* “Testing Criteria for a Complex Assessment Method for Industrial Design”, 34th International Business Information Management Association (IBIMA) Conference, pp. 653-664, 2019. WOS:000556337401026

[**Paper 3**] *Dumitrescu A., Ulmeanu M. E. and **Crăciun A. E.**,* “Testing the Technotope Concept”, U.P.B. Scientific Bulletin, Series D, **vol. 82**, no. 3, pp. 241-250, 2020. ISSN 1454-2358

[**Paper 4**] ***Crăciun A. E.**,* “Strategic outlook in industrial design assessment based on product category”, 10th International Conference on Advanced Manufacturing Technologies, **vol. 682**, no. 012006, 2019. DOI 10.1088/1757-899X/682/1/012006

[**Paper 5**] ***Crăciun A. E.**,* “A Study On Product Color Ratio Based On Aesthetic Principles In Industrial Design Assessment”, 35th International Business Information Management Association (IBIMA) Conference, 2020.

[**Paper 6**] ***Crăciun A. E.**,* “A review on quality from the perspective of industrial product design assessment”, Technium Journal, **vol. 2**, no. 7, pp. 303-309, 2020. ISSN: 2668-778X, DOI 10.47577/technium.v2i7.2180

[**Paper 7**] ***Crăciun A. E.**,* “Correlation between market segmentation, industrial product features and context in design assessment”, 11th International Conference on Advanced Manufacturing Technologies, **vol. 1018**, no. 012021, 2021. DOI 10.1088/1757-899X/1018/1/012021

[**Paper 8**] ***Crăciun A. E.**,* “A study on perceived value as a parallel between quality and kitsch in the design assessment of industrial products”, Technium Journal, **vol. 3**, no. 7, pp. 146-153, 2021. ISSN: 2668-778X, DOI 10.47577/technium.v3i7.4593