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Integrate system for materials classification in a multidisciplinarian materials library

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ABSTRACT

The amount of materials for designers to use in their projects has greatly increased in the last years. New formulations, new blends, new composites, new additives, and the achievements of nanotechnology and modern manufacturing processes contribute to this continuous increase. The correct classification and virtual and physical data provision assists in the materials selection process. This paper shows an integrated system classification by using the barcode reader available for android systems. Reading the codes in material samples are directed to the materioteca website. On the website the designer gets the technical information for this material.

Keywords: design education, sustainability, eco-design, library materials.

Introduction

The selection of materials is part of the designers usual work. The amount of materials available for designers to use in their projects has increased considerably in the last years. New formulations, new blends, new composites, new additives, besides the achievements of nanotechnology and modern manufacturing processes contribute to this continuous increase.

Choose the material to make the project real has always been among the major challenges of the designer. In the past, two factors were decisive for the choice: (1) the artisan's ability was essential; (2) the choice of materials was limited by the regional supply and the knowledge of the designer. Today, the manufacturing technology reduces the projective limitations. However, there are some constraints, such as cost, technology and regional labour which require special attention and remain to be limiting factors. This, added to the great offer of different materials, create doubts and uncertainties of several levels. These uncertainties increase when it becomes necessary to define the final composition of the material products.

In academia, various methods and projective tools were developed to assist in this task. Dias (2009) presents an extensive list that includes two different approaches: (1) quantitative systematic approaches developed by designers with essentially technical training such as mechanical engineers, civil engineers and material engineers; (2) general approaches with qualitative emphasis, usually developed by professionals from social applied areas or production engineering.

The methods developed at the university, when applied in practice, present two negative criteria: (1) large amount of data required to obtain a result, making the process very time consuming; (2) the complexity involved, both in the input data and in presenting the results, which are shown by means of careful and non-objective reading graphics.

After studying modern softwares of materials selection, such as the Granta Design (https://www.grantadesign.com/education/edupack) it was observed that the understanding of the final result depends on the prior knowledge of the user. Figure 1 illustrates a graph of Granta Design.

Most materials choice softwares are suitable for users who already have sufficient prior knowledge for multidimensional materials analysis. They are also suitable when designing products with established know-how. For inexperienced designers, or products with entirely new concepts, a more objective tool is required, with less input data and final numerical result. This favours the decision making. The initial results obtained in this way can then be used in more advanced software, such as the example used (Granta Design). This approach reduces the time of data inclusion and also the amount of options.

From the analysis of softwares to choose materials and considering the problems reported, this article aiims to develop an architectural design tool for materials selection. This should allow quick and objective application and simplified inclusion of data. The final result is given by quantitative numerical values. This allows a comparative analysis between competing materials.

The results presented here began with the development of a materials choice method called MAEM-6F, published in Ferroli (2009).

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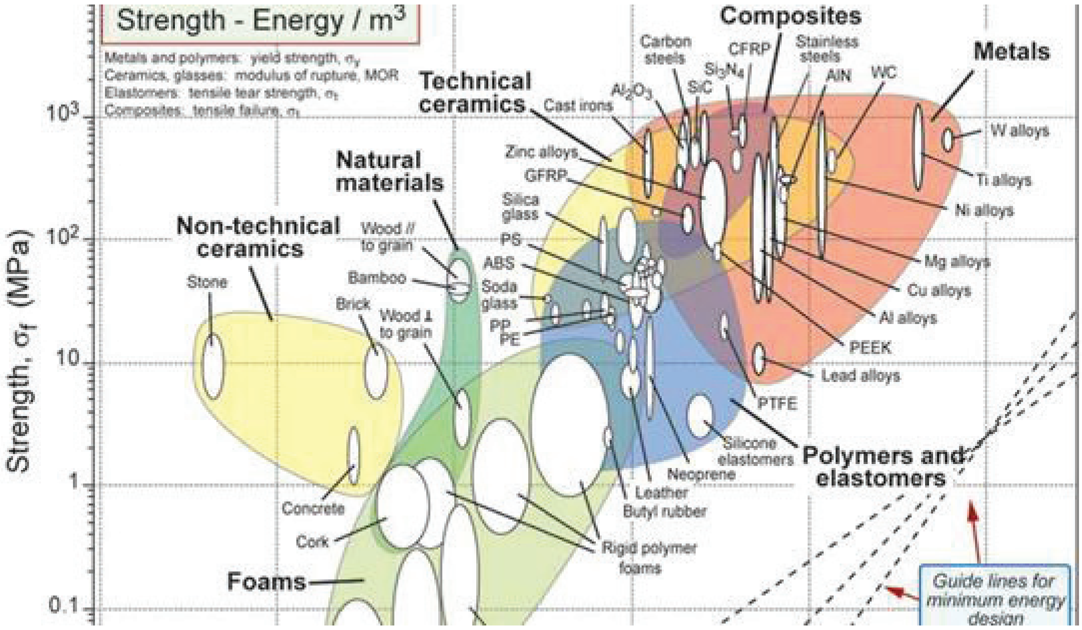


Figure 1. Illustrative image of Granta Design software.

Source: Granta Design Educacion (2016).

This method has been applied for six semesters in graduation courses of Industrial Design and Product Design. This experience led to some simplifications and adjustments. The resulting method has become a design tool that present fewer items in the tables and more objective results. The tool was denominated FEM – "Ferramenta auxiliar para Escolha de Materiais" and published in Librelotto *et al.* (2012).

After the conclusion of the project named "Materioteca with Sustainability Emphasis", shown in Ferroli *et al.* (2014), a study was begun to integrate the samples of materioteca with the virtual site contents. The reading of samples is performed by using a barcode system. All catalogued information about this material are automatically loaded into a spreadsheet. After the selection of the materials to be compared, the system correlates the information materials tables with the FEM tool tables. This gives the designer a quantitative numerical value that allows a quick and easy to understand comparative analysis. This paper shows the development stages of the integrated barcode samples with the technical information available on the materioteca site. This is divided into qualitative and quantitative information.

Implementation of materials library – history

According to Ashby and Johnson (2012), the selection of materials cannot be restricted to technical attributes. Environmental concepts have evolved recently. In Rio + 20, with the publication of the document "Our Common Future" (Rio + 20, 2016) there was an emphasis on design activities. In this regard, there was a discussion about the need to seek materials from renewable natural resources, and replacement of raw materials that are aggressive to the environment. These factors also impact on the recyclability, possibility of reuse and increased product life.

According to Barauna *et al.* (2015), currently the selection of materials takes into account the following factors: (1) production methods; (2) functional and structural demand; (3) market and user demands; (4) the final product price; (5) environmental impact; (6) lifetime; (7) trends and fashion; (8) consumption; (9) reputation and culture. Half of these criteria are qualitative and difficult decision making.

The use of materiotecas type is fundamental in the process of choosing material in a product. According to Van Kesteren (2008), four basic needs were identified by

Figure 2. Methods and criteria for materials selection.

European designers for a correct material selection task: (1) comparable information between materials of the same group or similar; (2) technical data related to the existing design problems in each case; (3) detailed information; (4) physical samples materials.

Walter (2006) proposes a method comprising an SDI (System Digital Information) to an SOC (Sample Ordered Collection – Materioteca). The author, in his conclusion, shows the importance of using materioteca in the design process.

From the relationship found in Dias (2009) it is possible to identify several common aspects between the methods for the materials selection. The author classifies as analysis methods, synthetic methods, similarity methods and inspiration methods. This is also pointed out by Ashby and Johnson (2012), relating these different methods of materials choice with the design requirements. The interrelationship requires the constant feeding of a database of materials and processes. The criteria for materials selection was retrieved from Librelotto *et al.* (2012), based on the MAEM-6F (as described in the introduction) as the starting point of this study. Figure 2 illustrates the procedure adopted based on what has been stated so far.

To exemplify, Figure 3 shows one of the technical files of materioteca. All data materials catalogued in the technical files follow the same pattern. This standard is maintained in the material information and graphic design. Initially, as shown in part A of Figure 3, the technical files of each material present a brief introduction. The main focus is on the LCA (Life Cycle Analysis). The technical files bring: basic concepts, properties, characteristics, a brief history of the material and main types. The materials are classified according to national and international standards. As can be seen in part B of Figure 3, the ACV of the material is analyzed in all its extension (cradle to cradle). In the final part, the technical files present examples of use in several areas (Architecture, Engineering, Design) and references.

The current listing of materioteca's website includes 18 tables, which are:

- Table 1: Natural, transformed and facing woods
- Table 2: Paper (plain), cards and cardboard
- Table 3: Ferrous metals (steel and cast iron)
- Table 4: Non-ferrous metals (alloys)
- Table 5: Sintered Materials – Powder metallurgy
- Table 6: Polymers – plastics (commodities, engineering, high performance)
- Table 7: Polymers – Blends
- Table 8: Polymers – adhesives
- Table 9: Cement, concrete and aggregates
- Table 10: Ceramic (common) and advanced ceramics (composites)
- Table 11: Natural materials (bamboo, gems, stones, leather, wool, and others)
- Table 12: Natural fibbers (ramie, sisal, jute, coconut, etc.) and synthetic fibbers
- Table 13: Natural and synthetic rubbers

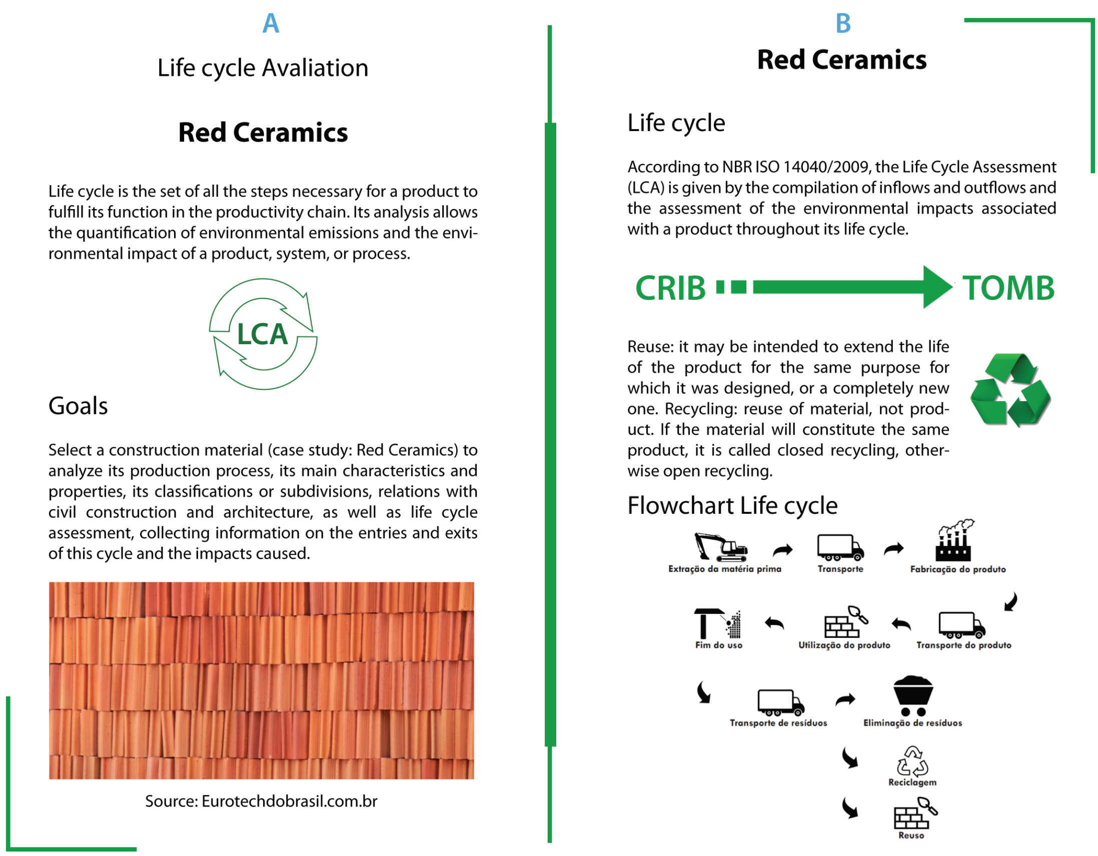


Figure 3. Example of material technical files in materioteca website (red clay).

Table 1. Natural woods, transformed woods and wood using for coating.

Geral	Group	Subgroup	Type	Main use
Wood	Natural	Conifer	Pinho, Pinheiro, Cipreste, Cedrinho	Linings, furniture, turned parts, civil construction
		Leafy tree	Aroeira-do-sertão, Sucupira amarela, Eucalipto, Jatobá, Cabreúva vermelha, Pau-marfim, Peroba-rosa, Canela, Amendoim, Imbuia, Cedro	Decorative sheets, furniture, civil construction, musical instruments, turned parts
	Transformed	Plywood	Compensado laminado, compensado sarrafiado, compensado naval	Furniture and interior uses, building construction
		Reconstituted wood	*Sofboard*	Thermal insulation, acoustic treatment
			Hardboard	Furniture
		Agglomerated wood	Particleboard	Furniture, building construction (wainscoting, flooring)
		Medium Density Fiberboard- MDF	*Standard* (MDF ST)	Furniture, toys
			Moisture Resistant (MDF MR)	Furniture kitchens, doors, windows, floors, skirting boards
			Flame Retardant (MDF FR)	Public Buildings
			High density (MDF HD)	Floors, stairs, chairs
	For coating	*Finish foil* (FF)	Decorative sheet for lamination in wood panels	Protection and aesthetic function
		Low pressure (LP)	Hot pressing decal	
		Wood Sheets (WV)	Wood sheets glued on the material	
		Melamine formaldehyde	MF	

Source: Materioteca de Produtos Sustentáveis (2016).

- Table 14: Oils and greases
- Table 15: Paints and varnishes
- Table 16: Nanotechnology materials
- Table 17: Advanced Composites
- Table 18: Materials not previously included

Table 1 shows the original table available in the materioteca website, referent to woods. All these tables are constantly updated. Some materials can be found, depending on the source consulted, in other places. The classification adopted by authors of the area depends on: (1) degree of these authors; (2) the country being considered; (3) the specific region within the country considered. It is common in materials, the use of regional terms.

For example, some authors classify woods in natural materials. Others prefer to place them in a separate group, named woods. Likewise, some authors state common and advanced ceramics in the same group. Others prefer to split into separate groups. There are significant differences in the classification of plastics. It was sought to use in the materioteca the most frequently found materials, both in scientific articles and in catalogues of suppliers and manufacturers. For example, plastic commodities is a term usually found in commercial publications and refer to the plastics commonly used (PP, PE, PS, PVC and PET). In technical books, this classification is not so common.

The materials classification adopted in the materioteca was carried out based on the following technical standards:

- ABNT (Brazilian Technical Standards Association);
- NT CSN (CSN Technical Standard);
- NBR (Brazilian Standard);
- NM (Standard Mercosul);
- SAE (Society of Automotive Engineers);
- ASTM (American Society for Testing and Materials);
- API (American Petroleum Institute);
- EN (Norme Euro);
- DIN (Deutsche Institut für Normung);
- BS (British Standard);
- SEW (Material Specification by Organization of the German Iron and Steel Industry);
- JIS (Japanese Industrial Standards);
- AS (Australian Standards).

Considered dimensions and process integrated reading in materioteca

In the process of material classification, after the construction of the classificatory tables, the next step was to classify the samples. These were identified according to the corresponding tables. At this stage missing samples were listed. It was also sought to establish a physical standard for all samples, with dimensions suitable for each group.

As shown in Figure 4, used to exemplify, the wood samples have all the same size (circumference and depth). When possible, samples of materials belonging to other groups were also manufactured with the same measure-

Figure 4. Physical samples of materioteca.

ments (length, width and thickness), as in the case of the bamboo sample shown in part B of Figure 4.

The physical uniformity of the samples facilitates observations by the user, such as: the relative weight between one type of material and another. Part A of Figure 4 shows several different types of natural and processed woods. The designer can, by simple tactile experimentation, compare characteristics of each material, such as relative weight, texture, colour, surface hardness, and others.

In the case shown in part B of Figure 4, there is another advantage, such as the possibility of comparison between the cross-section of various materials. In the specific case of the example, we have the following samples: (1) natural Teca wood; (2) processed wood laminated plywood; (3) processed wood compensated shingle; (4) natural Cinamomo wood (5) processed wood type MDF; (6) processed wood type OSB; (7) natural material: bamboo.

The identification of each material is made by the system of mobile and tablet Android type. It works by QR code (Quick Response), a two-dimensional barcode. The use of QR codes is free of any license. It is defined and published as an ISO standard. To use it, simply place the phone in the sample and connect the materioteca website. The material technical files are loaded automatically and always keeps the pattern shown in Figure 3. Figure 5 shows two examples of codes generated.

Based on Thompson (2015), the final stage presents the analysis of the relative sustainability of the material in question. This analysis is performed comparing this material with others that could be used for the same purpose (competing materials).

For this, quantitative values from 1 to 10 were established for all materials listed in tables 1 to 18 available in materioteca. These values take into account the following criteria: (1) availability; (2) durability; (3) recyclability; (4) biodegradability; (5) energy impact; (6) pollution index; (7)

Figure 5. QR code to paste in samples.

waste impact. Table 2 exemplifies the process showing the initial part of the overall picture, encompassing: natural wood, processed wood, plastic commodities and some engineering plastics.

The final analysis is currently in the process of computerization. It is proposed to correlate the data from the application of the FEM tool with those resulting from the application shown in Table 2. The process occurs by scanning the QRr code directly from the samples.

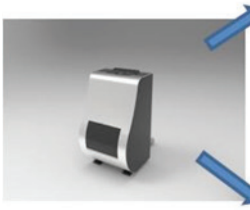
The designer receives quantitative final values for each factor considered (factory, aesthetic, ergonomic, ecological, etc.). This allows a quick comparison between possible materials for the project in question.

As shown in Figure 6, the numerical values are given individually (for each factor) and after they have been added. This allows the designer to see which factor is having greater influence in the final analysis. Figure 6 shows too the application of FEM on a project by analyzing two possible materials to a part of the product: PC (Lexan) or alkaline glass.

The FEM tool provides individual analysis for each of the factors. Thus, the designer (or design team) is free to attend or not the indication of this tool. For example, in a

Table 2. Comparative analysis criteria between materials

Natural woods	Avail-ability	Dura-bility	Recy-clability	Biodegra-dability	Energy impact	Pollution index	Impact of waste
Coniferous tree (Pinus, Cipreste, Cedro, Zimbro)	8	8	8	10	2	2	1
Arbor 1 (Peroba, Canela, Garapeira, Angelim)	8	8	8	10	3	2	1
Arbor 2 (Cerejeira, Pau-marfim, Jacarandá, Mogno)	5	9	8	10	4	2	1
Transformed wood	**Avail-ability**	**Dura-bility**	**Recy-clability**	**Biodegra-dability**	**Energy impact**	**Pollution index**	**Impact of waste**
Composed, agglomerated, OSB, MDF, MDP	8	9	6	7	6	4	3
Inflated reconstituted wood (with PU or PE)	7	9	4	4	6	6	5
Woods for coating (FF, BP, WV, MF)	7	9	4	5	5	5	6
Plastic commodities	**Avail-ability**	**Dura-bility**	**Recy-clability**	**Biodegra-dability**	**Energy impact**	**Pollution index**	**Impact of waste**
PE group (polyethylene): PEAD, PEBD, PEMD, PEL	8	8	8	2	8	6	5
PP group (polypropylene)	8	7	8	2	7	6	5
PS group (polystyrene)	8	7	7	3	8	7	6
PET group	8	9	8	2	7	8	6
PVC group	8	8	8	2	8	8	6
Engineering plastics	**Avail-ability**	**Dura-bility**	**Recy-clability**	**Biodegra-dability**	**Energy impact**	**Pollution index**	**Impact of waste**
Lexan group (PC)	8	9	7	2	7	7	5
POM group (POM)	8	9	7	2	7	7	4
Teflon group (PTFE, FEP)	6	9	5	1	8	7	6
Dayclear group (SPECTAR, PMMA)	8	8	8	2	7	7	5



FEM: Ferramenta para Escolha de Materiais. Planilha de análise de materiais.																			
Material analisado:				Grupo: Polímero				Sub-grupo: plástico industrial do tipo policarbonato - Lexan											
FATORES	Fatores fabris			Fatores sociais			Fatores econômicos			Fatores estéticos			Fatores ergonômicos			Fatores ambientais			
QUESTÕES	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P.F.	P x A	
1	1	1	1	2	1	2	3	3	9	2	2	4	2	2	4	3	3	9	
2	3	1	3	2	1	2	2	3	6	2	2	4	2	2	4	3	3	9	
3	1	1	1	3	1	3	2	3	6	2	2	4	3	2	6	3	3	9	
4	2	1	2	3	1	3	2	3	6	2	2	4	3	2	6	3	3	9	
5	1	1	1	2	1	2	3	3	9	3	2	6	3	2	6	3	3	9	
6	2	1	2	3	1	3	2	3	6	2	2	4	3	2	6	3	3	9	
7	1	1	1	2	1	2	2	3	6	3	2	6	3	2	6	3	3	9	
8	2	1	2	3	1	3	2	3	6	3	2	6	3	2	6	3	3	9	
9	3	1	3	2	1	2	3	3	9	3	2	6	3	2	6	2	3	6	
10	1	1	1				2	3	6				3	2	6	2	3	6	
11	2	1	2				2	3	6				3	2	6	2	3	6	
12	2	1	2				1	3	3										
13	2	1	2																
TOTALIZAÇÃO			23			22			78			44			62			90	**319**

FEM: Ferramenta para Escolha de Materiais. Planilha de análise de materiais.																			
Material analisado:				Grupo: Vidros				Sub-grupo: vidro alcalino submetido ao processo de têmpera térmica											
FATORES	Fatores fabris			Fatores sociais			Fatores econômicos			Fatores estéticos			Fatores ergonômicos			Fatores ambientais			
QUESTÕES	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P. F.	P x A	A. E.	P.F.	P x A	
1	2	1	2	2	1	2	2	3	6	2	2	4	2	2	4	2	3	6	
2	3	1	3	2	1	2	1	3	3	3	2	6	3	2	6	2	3	6	
3	2	1	2	1	1	1	2	3	6	3	2	6	3	2	6	3	3	9	
4	2	1	2	1	1	1	1	3	3	3	2	6	1	2	2	3	3	9	
5	2	1	2	2	1	2	2	3	6	2	2	4	3	2	6	2	3	6	
6	2	1	2	3	1	3	3	3	9	3	2	6	3	2	6	3	3	9	
7	2	1	2	3	1	3	2	3	6	3	2	6	3	2	6	3	3	9	
8	2	1	2	3	1	3	2	3	6	3	2	6	3	2	6	3	3	9	
9	3	1	3	2	1	2	2	3	6	3	2	6	2	2	4	2	3	6	
10	3	1	3				1	3	3				3	2	6	2	3	6	
11	3	1	3				2	3	6				3	2	6	2	3	6	
12	3	1	3				2	3	6										
13	3	1	3																
TOTALIZAÇÃO			32			19			66			50			58			81	**306**

Figure 6. Choice of the materials product by FEM.

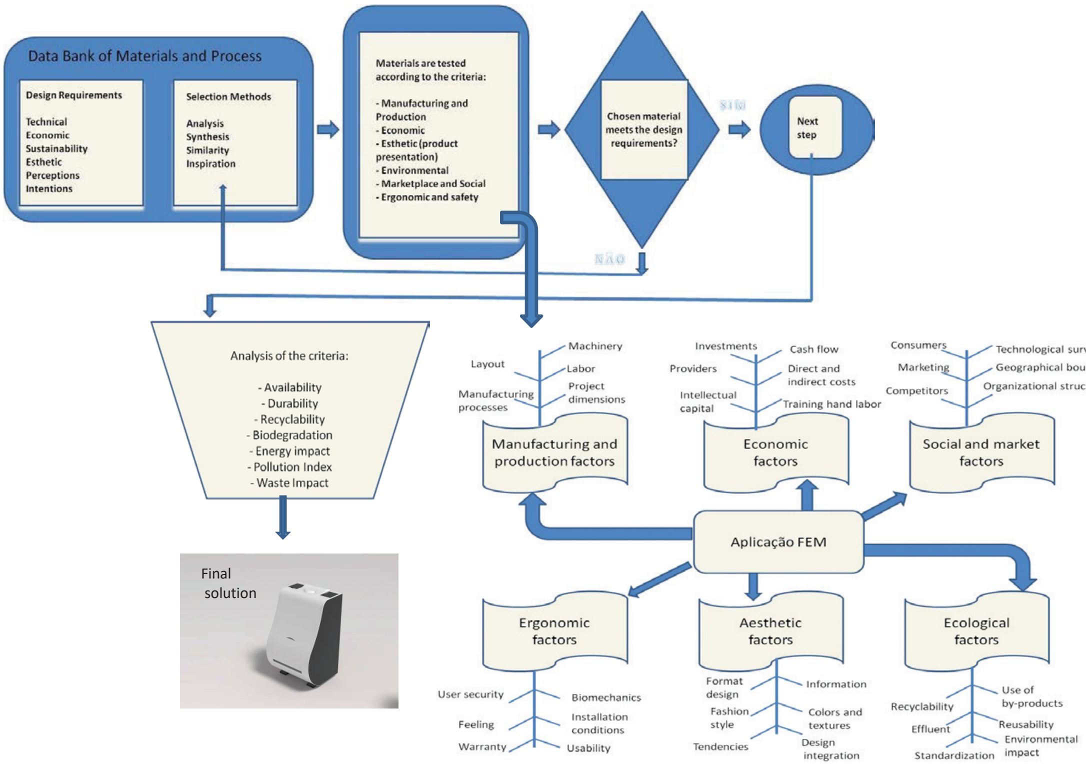


Figure 7. Complete process of materials choose.

product, the league ABNT 2024 (duralumin) got 340 points and AISI 304 stainless steel obtained 331. The aluminium alloy was therefore indicated as the best option by FEM. However, in an improved analysis regarding the use of the product and its target audience, it was found that ergonomic factors and social factors were more relevant than economic factors, for example. Stainless steel obtained a significantly higher score on these two aspects. The design team decided to use the steel in this case. Of course, in this example, the points difference was small. In case of a significant difference, only the total value of the FEM should be considered.

Figure 7 shows the complete process, which integrates the FEM tool with specific sustainability analysis. The FEM tool works as a filter, reducing the amount of material that would go to the analysis. The choice is timelier, focusing on the three dimensions of sustainability: economic, social and environmental.

Final considerations

The process of choosing materials integrating the six factors listed in this paper requires a multidisciplinary approach. Currently, the multidisciplinary approach is a necessity based on sustainability. This finding can be verified in most of the current publications on the subject, such as Santos *et al.* (2016).

Sustainability is not a function or problem of a specific group of professionals. It concerns everyone. We are all influenced by environmental issues. We all have influence on it.

The procedure proposed in this paper begins at the moment that the designer defines his initial priorities. Thus, it can be determined in the project that ergonomic attributes are more important than social, for example. It should be noted that the priorities depend only on the design team, and it is recommended to set up two factors as a high priority, two as medium priority and two as a low priority. One should not ignore any of the factors.

The tables were built in excel, so the numerical values are obtained automatically. The designer should only select the desired alternative in each question of the frame. The final value determines the most suitable material for each part of the project. The designer can use the final score (which is already considering the relative degree of influence of each factor), or evaluate the factors separately. Previous results, competitor products or even the nowhow established can be decisive for this analysis. Project team's expertise and specific advice may also have ultimate influence.

The inclusion of the Quick Response system facilitated the entry of data, reducing the time spent in completing the questions. The last analysis concerns the correlation between the values obtained from the FEM with the specific approach of sustainability, analysed with the sub frame filling which is based on the values shown in Table 2 of this paper.

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