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Julio Cesar Rivera Pedroza[1], José Rafael González Díaz[2], Bernabé Hernandis Ortuño[3]

[1] PhD candidate in the program of 'Design, Manufacturing and Management of Industrial Projects' at the Polytechnic University of Valencia (UPV), Spain. Industrial Designer, National University of Colombia. juriped@alumni.upv.es

[2] Doctor by the Polytechnic University of Valencia, in the program of 'Methods and techniques of industrial and graphic design'. Master in Design, Management and New Product Development , Spain. jogondia@doctor.upv.es

[3] Doctor Industrial Engineer, researcher in the field of design and systemics. Member of the Research and Design Management Group. bhernand@degi.upv.es

Abstract

The research deals with an approximation to systemic design focused on sustainability, analyzing issues affecting the conceptualization of a product-system or service, in the initial stages of the design process, determining from a qualitative perspective on this phase of the project, a set of variables that are articulated both from basic design criteria as well as from sustainability criteria. For it, one resorts to the use of a multiobjective design model, in order to manage data, information and knowledge as well as its networks of relationships. It starts from the consideration of multiple sources of uncertainty that are reduced by a filtering process of the outer system, from an approach proposed for such purposes. Similarly, is raised the highlighting of variables that contribute to complement the emotional aspects, spiritual and scale of values related to users or consumers, as a strategy to assist in the process of providing a new pillar to the triad of sustainability, traditionally supported by environmental, economic and social pillars. For the description of procedures, structures and functions, a case study is presented in which are outlined the intrinsic qualities of a reference system and their interaction networks, starting with the filtering process of the outer system, till the obtaining of the key variables that have greater impact on the definition of formal, functional and ergonomic objectives in the inner subsystems.

Keywords - Immaterial Context, Material Context, Sustainability, Systemic Models, Systemic Thinking.

Introduction and mutiobjective design

The global environmental crisis of which there is much talk in the recent times is the result, among other factors, of instinctive and thoughtless development processes of societies on the environment. In this context, the role of the designer in the development of a sustainable society is not simply creating "sustainable products", but rather to imagine products, processes and services that promote a generalized sustainable behavior (Stegall, 2006). To achieve this, it is essential to accost concepts such as multi-objective design through the approach of authors like Inoue et al. (2012), who propose a scheme that besides the physical performance of products, integrates aspects of sustainability, from a global perspective of environmental protection, not at any level, but from the early stages of the design process. Similarly, these authors highlight the importance of considering multiple sources of uncertainty in the decision-making processes in these phases. This multi-objective sense is characteristic of a systemic approach, and among other things, can enhance the understanding of a multidimensional vision with strong interactions that are not necessarily linear (González, 2013). In this same line of argument, Yan, et al. (2009), propose a system for sustainable product conceptualization in which the integration of functional, cognitive, marketing and merchandising perspectives, along with sustainability, has become imperative (p. 1618), and as Inoue et al. (2012), they point out the importance of addressing this process in the initial stage of product conceptualization.

For the development of a product, service, system or sustainable process, it is important the identification of a model or method that makes viable and allow the consideration of sustainability criteria in their different stages of development. Besides the various sources of uncertainty in the initial stages of the design process and conceptualization, authors such as Yan, et al. (2009), state that the impact of multidisciplinary integration and attention to product life cycle have not been examined thoroughly. All these aspects together, need to be understood from a broader view and under a systemic approach, because unlike the analytical approach, the systems approach can encompass all the elements of the studied system and their interactions and interdependencies (de Rosnay, 1979).

In this sense, this research resorts to the concurrent systemic design model proposed by Hernandis (1999), to manage the contents of multiobjective design inherent both structural and functional aspects of the system under study, as well as the interactions and interdependencies revolve around the analysis of context and conceptual variables that strengthen sustainability criteria and performance in the development of products and/or services, including the particularities concerning uncertainty, multidisciplinary and multidimensional integration. To explain the procedure one resorts to conceptual modeling of a product-system through a case study.

As a starting point, through the concurrent design model, the process focuses on the determination of the characteristics and components of the outer system, since there are the suprasystems that may define the variables that enable the configuration of a product or service, and it is at this phase of conceptual design in the early stages of the process, in which the criteria are to be applied to generate a sustainable response to the problem and not after. Bonsiepe (1978) in this respect already mentioned in the seventies the obvious fact that an industrial design that seeks ecological validity should forcibly be directed towards a new point of view that does not consider the isolated object, but as part of a whole complex of interactions which he called at the time as *systematic approach* (p. 55).

Therefore, this working paper aims to make an approach to systemic design focused on sustainability, analyzing the factors affecting the design of a product or service from the initial stages of conception, considering from the basic design criteria and sustainability criteria, to the tangible and intangible aspects that include cognitive and emotional components of products and services. Löbach (1981) mentioned the specific weight that practical needs had, but leaving aside, noticeably and widely, product configuration considering psychological and social needs related to the immaterial context.

Based on the above, in the research three fundamental objectives are raised. The first one is related to the definition of variables that allow the configuration of a sustainable product or service, through a multi-objective design model that allows its traceability in the system and its use in design and conceptualization, from the early stages of the process. Secondly, there is also raised the determination and putting into relief within this set of variables, those that help to supplement the emotional, the spiritual and the scale of values inherent to users or consumers in the terms proposed by authors such as Wigun (2004), González (2013) o Wahl & Baxter (2008), relating to providing a new pillar to the triad of sustainability traditionally supported in ecological, economic and social pillars, as a means to highlight the importance of the essential motivations of individuals, as a strong force for change through real demands and aspirations, which cannot be conducted and defined only through physical facts. Finally, it is proposed an approach to filtering and derive inputs from the outer system to the reference system, through tangible and intangible considerations as a starting point.

1. Strategic vision: design for sustainability

The need of a Model

The research has a mixed approach which includes analysis of both qualitative and quantitative data. At this stage of the investigation which covers the contents included in this working paper, will be considered primarily qualitative issues that will underpin the determination of variables, and in a subsequent phase, the obtainment of empirical data by different procedures will be addressed, starting from a questionnaire to experts. In this way, the contents of a qualitative nature, on which has been structured the initial information, include the preliminary modeling of a case study to analyze and describe the interactions that characterize the operational framework of the variables in the reference system, by employing the systemic model of concurrent design of Hernandis &

Iribarren (1999). For the development of a product, system or sustainable process is important to identify a model, tool or methodology that enables and facilitates the consideration of sustainability criteria in its different dimensions. One resorts to an action of this nature, given the need to replicate the experience with different product/service systems as well as managing data, information and knowledge from a multi-objective perspective that includes besides multiple sources of uncertainty about the phenomenon under study at the beginning of the design process, having then a valid framework for comparative analysis and contrast the performance of two or more systems simultaneously; situations that can be represented in this reference model.

Moreover, as pointed out by Yan, Chen & Chan (2009), although a number of studies have been conducted on sustainable issues in many aspects, impacts such as multidisciplinary integration and product life-cycle consideration have not been thoroughly investigated, and in this respect, these two dimensions can be considered in the systemic model of concurrent design from the early stages of the design process. These authors also resort to the use of a model for addressing the conceptualization phase under a sustainability perspective, for which propose an *ad hoc* system, which investigates the integration of functional, marketing and commercial perspectives within the sustainability, principles that are analogous to those proposed by Hernandis and Iribarren (1999) in their approach to concurrent design model.

Approach to the Systemic Model of Concurrent Design

In the Concurrent Design Model of Hernandis & Iribarren (1999), consisting mainly of the outer system and the reference system (system under study or product system) (p. 56), the *Outer System* is composed of all that surrounds the phenomenon and which in turn serves to raise the design problem. This is the starting point for obtaining the data from the exterior affecting the problem. Namely, in this system are considered environmental aspects which provide considerations and constraints that influence the design problem. For its part, the reference system is mainly composed of three basic subsystems (formal, functional and ergonomic). These subsystems are at the same level and no predominance of one over another (are isosystems) in order to facilitate more detailed analysis of the system under study. These subsystems at the same time are composed of other subsystems, components, variables, objectives and elements. These will be the maximum degree of disaggregation proposed. In this sense, the model of Hernandis and Iribarren (1999) leads to a disaggregation by levels, in line with approaches such as those of Munari (1981), who notes that decomposing the problem into its integrating elements means to discover numerous sub-problems and a particular design problem is a set of many sub-problems.

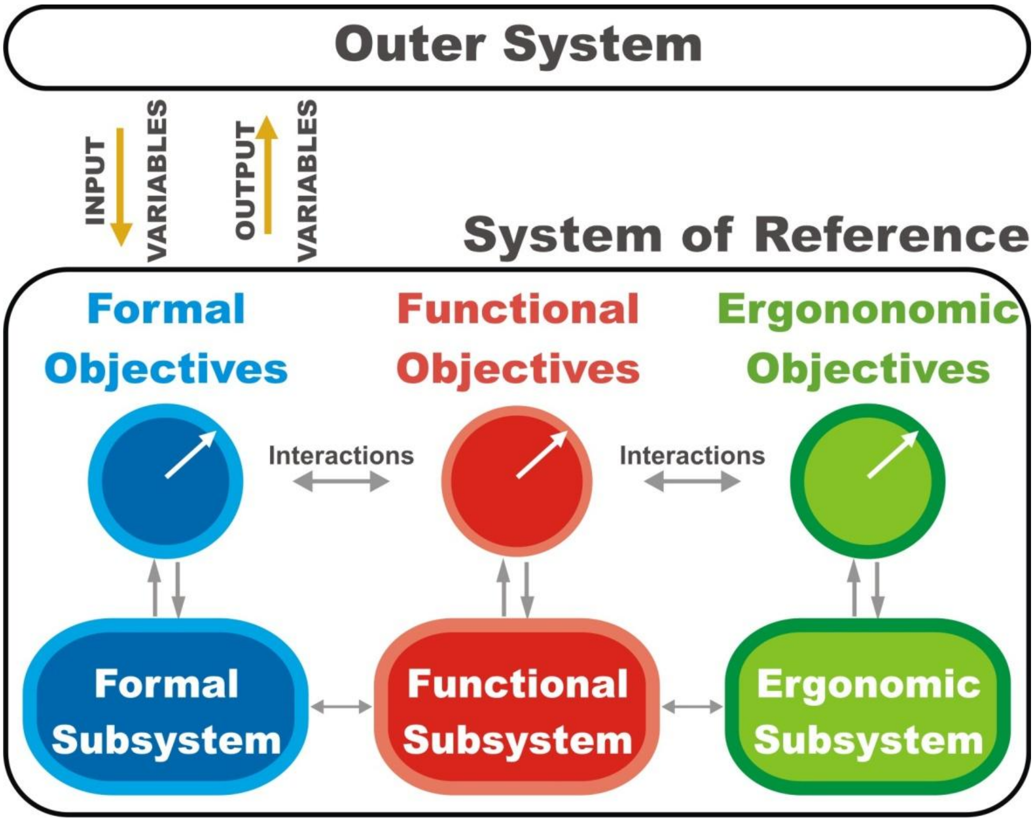

Figure 1. Theoretical modeling (Hernandis & Iribarren, 1999)

For the application of sustainability criteria in the development of products and services is important to consider the initial stages of the design process, since as stated by Manzini & Vezzoli (2008), improving the product impact is more probable during the initial stages of development, when the innovation has greater magnitude (p. 238). Given the above approach arises one of the specific objectives of this analysis, which seeks to establish how from an early stage in product development by analyzing the *outer system* in the concurrent design model, one can reach to design and develop products with a high degree of sustainability. To do this it is necessary to consider all suprasystems and these can be from raw materials to production or maintenance, etc. But in this case would be considered in addition to the above (which are more focused on factors related to the form, function and ergonomics), others such as recycling, repair, re-use, natural resources, environmental emissions, disuse, etc. Being sustainable design, the degree of importance and significance depends on the sustainability criteria. One can say that suprasystems like shape, transport, joints, packaging, among others, may have less relevance facing other suprasystems.

But this does not mean that one should discard the intrinsic potential of sustainability that these can have, since sustainability even if it appears, may be present in the form (by setting lower volume elements or materials and equal or greater efficiency), in transport (by optimizing the collection and distribution systems, minimizing CO^2 emissions) or joints (by developing assemblies with the same material of the pieces together or compatible materials to prevent separation for recycling). Also it should be noted that aspects such as color or psychology, may not be relevant and not be considered of vital importance in the analysis (Rivera & Hernandis, 2012c, p. 120).

The Material Context

In this context aspects related with physical concepts of the projects are considered, in which are analyzed the characteristics, materials, production, energy, etc., as well as the relationships and interactions of elements already developed and the medium in which they are used. Wahl & Baxter (2008), refer to the intentionality behind the design in material terms, expressed through interactions and relationships formed by consumer products, transportation systems, economies, systems of government, settlement patterns, and the resources and the energy used, with the complexity of social and ecological processes (p. 74). Under this perspective it is proposed that during the planning and development of a solution to a design problem should be performed a *physical analysis* in which similar *references* or related projects as well as its *surroundings* are considered, in order to identify aspects of its interactions, forms of production, legislative aspects applied or involved, and everything related to the material context of the project.

The immaterial Context

In this context analysis are formulated related to psychological and sociological concepts that relate to the different ways of perceiving the world, ideas, value systems and aspirations of society. Wahl & Baxter (2008) also point out that immaterially, our organizational ideas, worldviews and value systems express how we give meaning to our experience of reality through metadesign (p. 74). This formation of sense through metadesign, goes beyond the tangible aspects of material context, to achieve a relation regarding concepts and psychological and sociological assumptions. As stated by Stegall (2006), if the new goal is to design products that are more than just non-toxic or recyclable, but actually serve as tools to form people, lives and values, then we need to step back and examine what traits, values and behaviors, people must have in a sustainable society (p. 58). This should be done from a holistic approach involving various academic and professional disciplines, visions and approaches, so that the responsibility of a design response does not rest, as in many cases in one person (designer or configurator) who in many occasions may not have the necessary tools to provide optimum solutions to problems. What is intended with the approach of the psychological and sociological analysis is the study of the *trends* that are handled in certain areas and *users* to whom those projects would be directed (be them products, systems or processes) in order to integrate ecological, cultural and social processes in the search of solutions to design problems.

2. Design & Sustainability Context. Preliminary approach

Physical performance and basic design criteria.

For the determination of Basic Design Criteria, some methods, references and design models were analyzed, such as those proposed by authors like Bonsiepe (1978), Jones (1982), Archer, French, Löbach (1981), Munari (1981), Bürdek (1994), Hernandis (1999) y Cross (2003), among others, in order verify if there were matching common aspects among them, regardless of the context or type of problem. Most are focused on material aspects in product development, so that the principles with which the scales are raised to value the basic design criteria change. In this regard Löbach (1981)**,** recognizes as belonging to the aesthetic criteria of the objects, aspects such as the shape, material, surface, color, order and complexity; Pahl & Beitz (Cross, 2003, p. 94) in one of their projects define criteria such as energy, operating conditions, test requirements, life expectancy, production, operation, maintenance, amount and costs among others. Pighini (1983) for his part, proposed as design criteria for a city car: the cost, performance, manufacturing and resistance, each with its subcategories, and Hernandis & Iribarren (1999) propose that such criteria need to consider maintenance, ergonomics, operation, endurance, finishes, components, joints and raw materials among others. This way it is possible to observe that although some approaches have *basic design criteria* in common, approach and the definition thereof may vary depending on the particular project, and in many cases incompatible when applied to products and services.

Sustainability.

With regard to establishing sustainability criteria from the initial stages of the design process, as stated by Bürdek (1994, p. 58), although previously -in the 70's and 80's- a number of ecological requirements were raised; in many cases were not taken into consideration others such as waste collection, pollution reduction, reuse of raw materials, the duration and product repairs. And as for the satisfaction of user needs, considerations were purely functional, as suggested Löbach (1981), focused solely on the process of using. Subsequent approaches such as those of Vezzoli & Manzini (2008), argue that proper identification of environmental priorities is crucial for guiding design efforts and eventually establishing the selection criteria for alternative solutions (p. 238), with a proposal based on the consideration of some of the components of the Life Cycle Assessment (LCA) (SETAC, 1992) establishing a *Design Criteria and Guidelines* (Vezzoli & Manzini, 2008, p. 263) that can be summarized in seven basic concepts: Minimize materials consumption, Minimizing energy consumption, Minimizing toxic emissions, Renewable and bio-compatible resources, Optimization of product lifespan, Improve lifespan of materials and Design for disassembly. These design criteria have key points in common with strategies like the LiDS-wheel (Brezet & van Hemel, 1997), as both tools consider stages of product life cycle but like the LCA, its implementation in the initial phase of design process produces mainly qualitative data, reason why it could not be determined the actual environmental impact of future products and services, but in any case, constitute an important contribution to the definition of specific content inherent to the subject, and of concepts such as *strategic design for sustainability* proposed by Manzini & Vezzoli (2003), in relation with the new competencies of design and long-term value creation through sustainability. In this sense, the authors emphasize the value of the material through the immaterial, capable of reorienting mental schemes, going from designing physical products only, to product-systems which meet specific customer demands, while also reorienting unsustainable practices into new practices and attitudes of production and consumption. In the same line of thought, Maxwell *et al*. (2006), propose two key strategies to improve the environmental benefits of products and services offered and are summarized in *functional* aspects and *systems thinking*. Issues identified to achieve the functional innovations required include focusing on the provision of functions to meet human needs (as distinct from products) and system based solutions. Likewise the authors state that the delivery of system focused offerings incorporating a product, service or PSS and the infrastructural, consumer, institutional, network and user behaviour context within which it operates is seen as necessary for environmental improvements, and this way material aspects are balanced and immaterial aspects are potentiated.

In this scenario, in relation with the criteria and qualities of the phenomena related to research, the material and the immaterial context are raised, as a way to identify criteria that validate the assumptions or knowledge about the identified concepts of perceived reality.

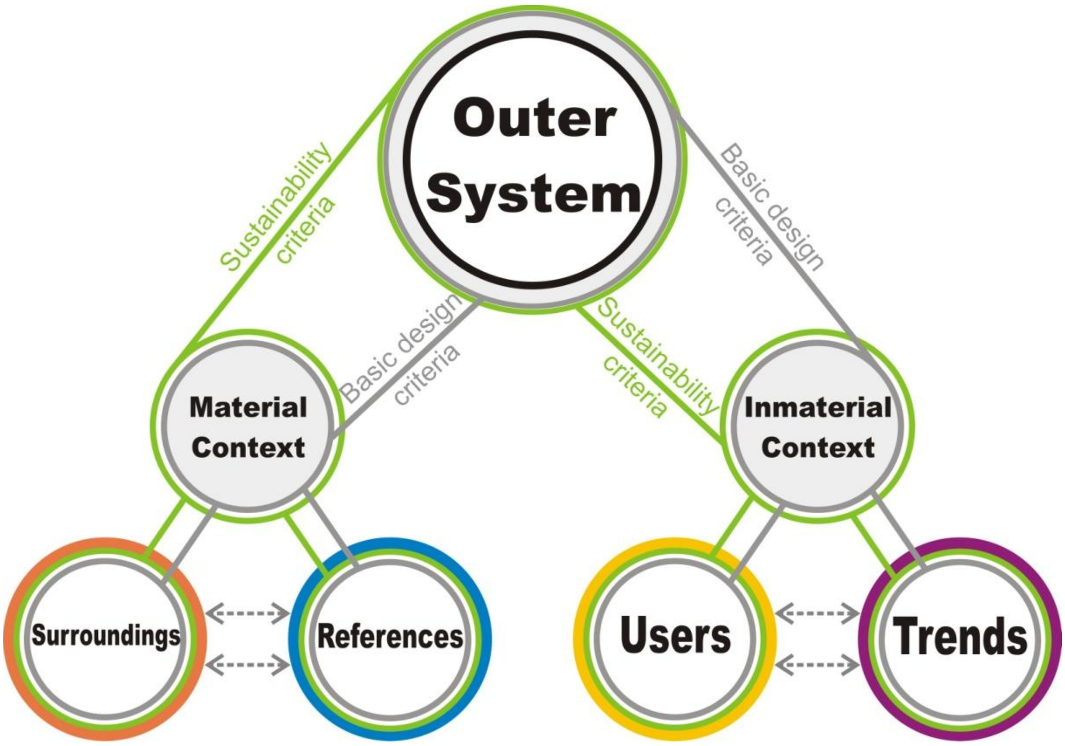

Figure 2. Derivation scheme of the outer system (Rivera, 2013)

3. Case Study

A case study is proposed to illustrate the effects of the application of the derivation of the outer system in a particular design problem. In this case the analysis of the outer system components is performed as well as the criteria taken into account for the design of a 'Vertical garden for housing interiors' in which ornamental or consumption plants can be cultivated (Rivera & Hernandis, 2012a). This study is focused on the characteristics and outer system components of the model, combining these with a tool for sustainable design. It is considered that this suprasystems analysis can define the variables that allow the configuration of a product, system or process and generate a sustainable response to the raised problem.

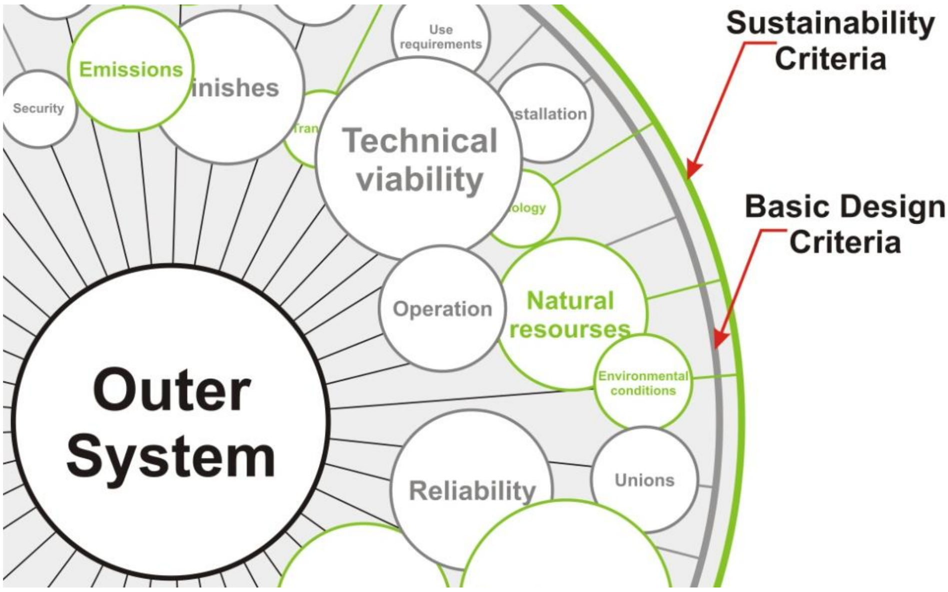

Figure 3. Study case - Outer system analysis (Rivera, 2013)

The outer system is the starting point of the analysis. In this are considered both the basic design criteria such as color, finishes, resistance, aesthetics, joins, production, etc, As well as sustainability criteria such recycling, obsolescence, emissions, repair, energy and supplies consumption, etc. That is, from these two approaches, are considered all the elements that from the outside can affect the product (or a service if it was the case) as the reality which surrounds it and that in turn, raises considerations and constraints that influence the design problem.

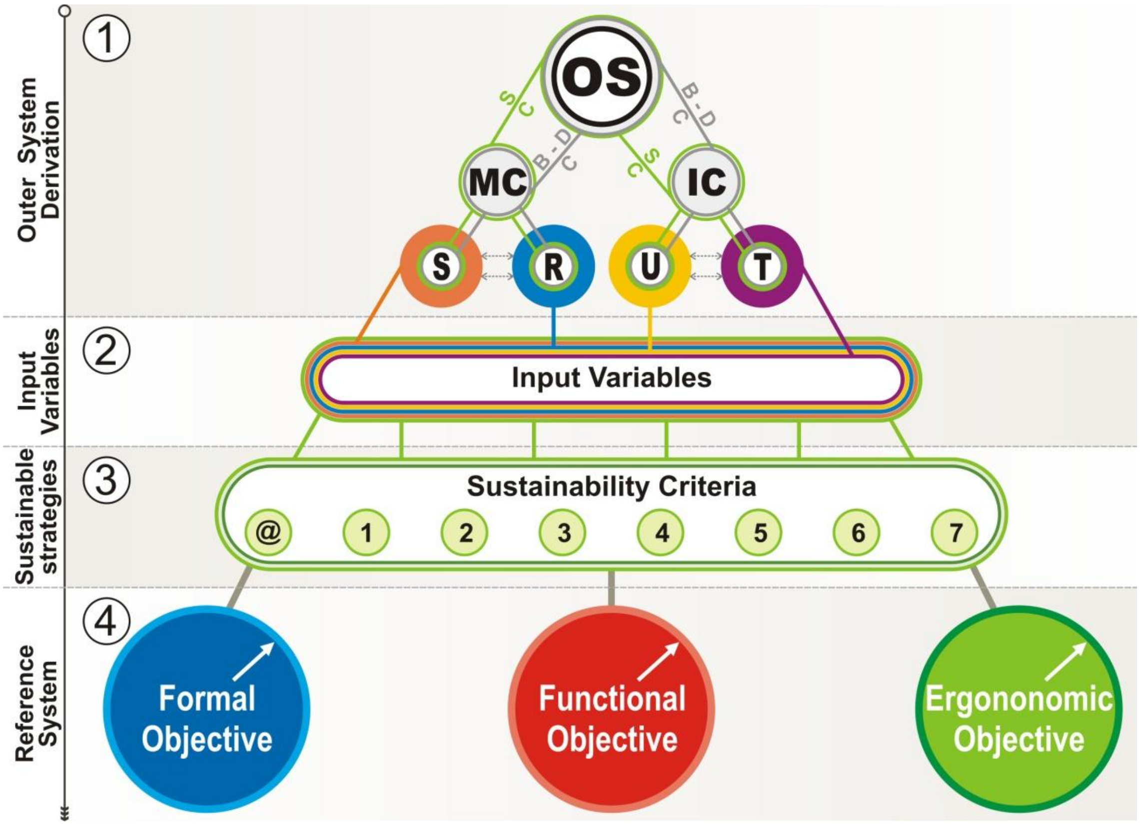

Figure 4. Derivations of the outer system and sustainability strategies (Rivera, 2013)

As mentioned above, the multidisciplinary and multiobjective approach raised also makes that apart from the derivation of the outer system in material context (MC) and immaterial context (IC), two more derivations are raised for these contexts. On one side would be the *surroundings* and *references* (for MC) and on the other would be *users* and *trends* (for IC). The analysis of these suprasystems combined with sustainable design strategies facilitates the generation of the input variables that would result in the project's requirements.

The integration of a tool or methodology for sustainable design or eco-design is performed by applying the principles of the wheel of strategies LiDS-wheel (Brezet & van Hemel, 1997) in the concurrent design model, since its principles can be applied on the conceptual stage in the development of a product and a process. In the analysis of the input variables, characteristics of the project are identified and are defined the requirements and previous determinants in its general aspects before performing the subdivision into the basic subsystems. In this step besides analyzing requirements and determinants, must be applied sustainability criteria into systemics (Rivera & Hernandis, 2012b, p. 5).

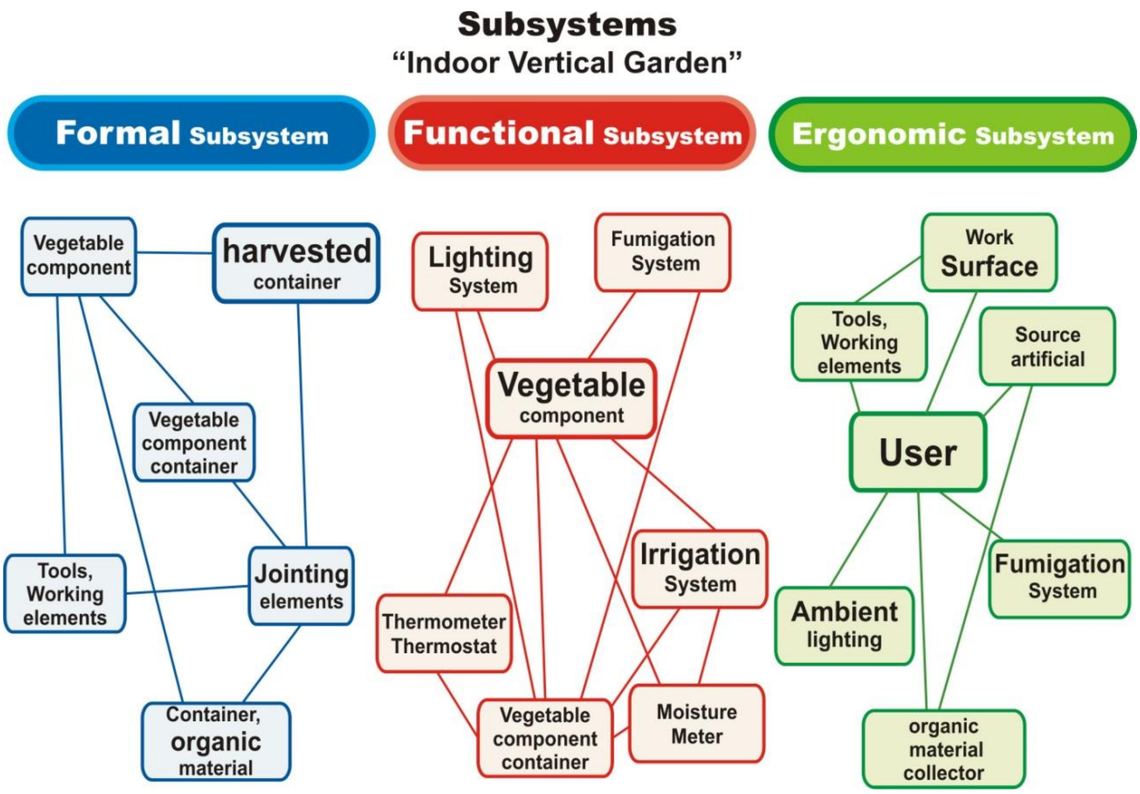

Figure 5. Study case - Basic subsystems

The components of the object under study are determined based on theoretical modeling phase. Than it result systems and subsystems that have a relationship to each other by means of the variables analyzed in this phase. This is shown in the figure 4that include the main elements of the element in the basic subsystems and their interrelationships.

Subsequently, is carried out a structural analysis that considers the relationships between the subsystems to achieve a more approximate definition of the components by using schemes and informatics models. This is done for the purpose of projecting the objectual context, and of services that would conform the system.

In this case study, the core subsystems of the vertical garden will be divided into components (subsystems, assemblies and subassemblies) and elements (minimum units with its own entity). According to the above approach, the basic subsystems (form, function and ergonomics), will consist of significant subsystems, but these in turn must comply with the formal, functional and ergonomic objectives raised earlier.

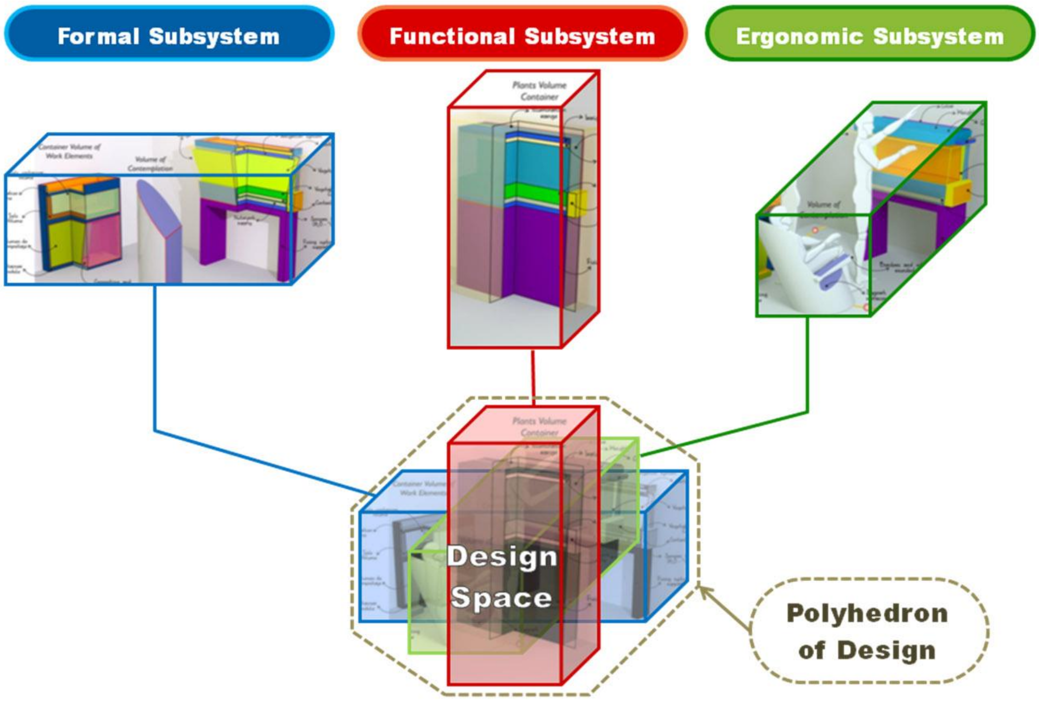

Figure 6. Study Case - Basic Subsystems

After performing the conceptual description of the product composed by a theoretical analysis, formal and structural, is necessary to generate feedback to see if new subsystems, components or elements of the system under study have arisen (Rivera & Hernandis, 2012a, p. 763). For it the previous analysis are evaluated in order to reflect the results in the diagram of Figure 8, which shows the new components detected. To generate an optimal result is necessary to consider the volumes, surfaces and contour limits of the element over which the analysis has focused, and which contains a 'positive geometry' as well as a 'negative geometry', to delimit the geometric constraints to accomplish.

The negative geometry is usually of immaterial order and allows considering aspects such as the encirclement of use, for example. The sum of positive and negative geometry, becomes in the 'design space' or design polyhedron from the geometric point of view. In the conceptual design proposal of the vertical garden, are evaluated different design architectures that are included into the design space and allow the structuring of the project by the delimitation of both tangible and intangible considerations.

After defining the configuration of the element through a formal sketch, one proceeds to develop the proposal parametrically using three-dimensional modeling software to specify the components, their functions and their network of relationships in the system. At this stage is reached a higher degree of definition of the element, as in the modeling are set up the components, their surfaces and details in order to define its configuration and its finishes with the highest degree of compliance with the objectives in terms of form, function and ergonomics. On this level are also defined technical-productive details with the necessary specifications for its construction.

Conclusions

Through the development of content covered in the research, it has been possible to determine those aspects that support the definition of sustainability criteria and variables for the purpose of addressing the configuration of a product or service in the early stages of the design process, through a systemic model of multiobjective design used to manage data, information and knowledge, but above all, to highlight its networks of interrelationships and dynamic interactions.

Similarly, have been highlighted within the set of variables, those that complement the sustainability triad traditionally supported in the ecology, the economy and the social aspects, to accommodate content inherent to an emotional dimension, affective and of scale of values, closer to the immaterial and to the driver of change represented in people who use and consume products and who are increasingly demanding more respectful solutions towards environment.

On the other hand, it has been established the proposed approach to perform the filtering and the derivations from the outer system through considerations not only material but also immaterial and in that sense, it has been achieved from a qualitative point of view, a schematic model suitable for making decisions on integration between basic design criteria and sustainability criteria, through a case study where it is possible to understand the outer system filtering by means of the proposed approach at different levels of content and networks.

Finally, to highlight that about these contents, it is possible to undertake a more advanced modeling of the system, by incorporating empirical data to be obtained in the subsequent phases of the project and delve into the quantitative aspects of the proposal.

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