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# ANALYSIS AND IDENTIFICATION OF RESEARCH OPPORTUNITIES IN PRODUCT DESIGN USING THE MULTIDIMENSIONAL PROJECT MODEL

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## 1. Introduction

The project theory proposed by Gomez-Senent [1998] identifies six dimensions that must always be present in a project: Process, Factors, Metaproject, Techniques, Tools and Phases. The Process Dimension is related to the activity of thought in problem solving; the Phases Dimension refers to the morphology of the project; the Metaproject Dimension is associated with the project organization and communication; the Factors Dimension, with the environment in which the whole project takes place; the Techniques Dimension is related to methodologies taken from the sciences and disciplines that help solve specific problems; and last, the Tools Dimension is associated with the physical elements that allow the support of techniques.

With the purpose of finding research opportunities under a broader perspective of product design, the methodology followed in this study compares the classical theories of product design with the model proposed by Gomez- Senent [1998] in order to identify dimensions that have not been dealt with in depth in such theories. The Factors and Metaproject Dimensions were the ones with major absences. Based on the dimensions found, a current literature review is done to identify research contributions and in this way determine the research opportunities in product design.

The review of current literature allowed to identify contributions in the Factors Dimension of the following external factors: Economic, technological and human factors [Dickinson, 2006; Leydesdorff et al., 2006], the design focused on the human being [Rubin, 1994; Suwaa et al., 1998; Jordan, 2000; Naville et al., 2005], methods to obtain measurable information on factors of qualitative characteristics (perceptions, emotions), the relationships of the configurative product properties [Shutte, 2002; Kleff et al., 2005; Chang et al., 2006] and the innovation product value supported by the relationship between the different actors of the context: scientific, business and social actors[Leydesdorff et al., 2006]. In the Metaproject Dimension, research work is found related to the analysis of multidisciplinary teams [Miranda et al, 2007; Rafols and Meyer, 2006], the conjunct work of design and manufacturing teams [Arcidiacono, G. Et al, 2006; Fagestrom, J. Et al., 2002; Sahlin, M., 2000], the characteristics of the new temporary organizations focused on projects, not on functions [Packendorf, J., 1995; Soderlund, J. 2004], as well as the negotiation processes in working teams regarding the complexity topic [Suh, N., 2006].

Opportunities for research about multidisciplinary and multiorganizational teams in product design have been identified in empirical studies with representatives from the university, the enterprise and the user, involving exploration of the topics associated with the selection of workteams, communication processes and decision-making cooperatives. On the other hand, possibilities for

research are opened regarding evaluation of the perceptions of the user related to the product, the type of responses associated with these perceptions, as well as the relationship that exists with the product configuration parameters. In particular, this paper has allowed the authors to define research works, that are currently in development, concerning aspects associated to the perceptions of the consumer, the sensory, emotional, and cognitive evaluations of the user with regard to the product, and also aspects related to the expansion of the Axiomatic Design model to involve a multidisciplinary project team and the consideration of non-functional requirements within the model proposed by Suh [1990].

## 2. Gomez-Senent's Multidimensional Model

The theoretical model proposed by Dr. Eliseo Gomez-Senent is the groundwork for this study. It is extensively explained in his book "The Science of the Creation of the Artificial" published on 1998. His multidimensional model is based on the conception of the project as a set of interrelated intellectual activities called dimensions. The proposed model requires two conditions: that each dimension is present in any kind of project and that the presence needs to be continuous throughout the whole project [Gomez-Senent, 1998].

Gomez-Senent proposes a model of six project dimensions organized in two groups: one of intrinsic type, associated to the design, and one of extrinsic type, regarding the design environment. The Process and Phases Dimensions are situated in the first group, the intrinsic type; and the second group, the extrinsic one, is made up of the Factors, Metaproject, Techniques and Tools Dimensions. Figure 1. Shows a global aspect of the model where a designer or design team enters in one of the levels of the sphere and according to their degree of knowledge starts at a divergent stage, in the resolution of the problem, if it is over the equator or convergent stage, if is above the equatorial axis. In this representation, each of the dimensions of the project are related to a wedge of the sphere, so that when carrying out the project, all dimensions should be taken into consideration [Gomez-Senent, 1998].

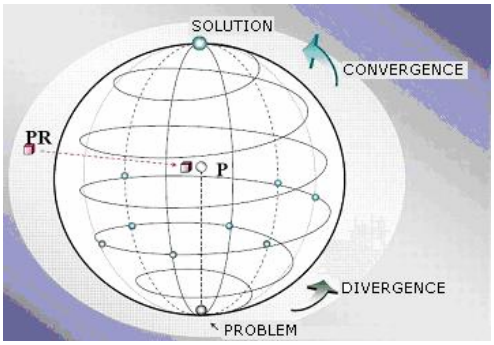


**Figure 1. Gomez-Senent's Multidimensional Model Representation**

The multidimensional model of Gomez-Senent is a structure that serves as a methodological basis of analysis for the evaluation of theory development in design, particularly in the field of product design since its configuration allows to confront each of the factors or internal and external agents that affect the designer in the process of developing new products in a systemic and controlled way. In addition, it identifies deficiencies to be corrected, and thus optimizes the results of the process.

## 3. Comparative analysis between classical product design theories and Gómez-Senent Model

A revision of some relevant theoretical and methodological project models in the field of product design proposed by different authors such as Jones [1978], Suh [1990], Puhg [1991], Palh and Beitz [1995], and Hubka Eder [1996] and Cross [1998] was made having Gomez-Senent's Six Dimension Model [1998] as the model of comparison. The results are shown in Table 1 and Table 2. By

comparing the models and reviewing each of the dimensions, the following common points between the authors have been found:

- Process Dimension, associated with the process of problem solving: The importance of the division of the problem, of the resolution process through intellectual activities and of the evolving and iterative nature of the project.
- Phases Dimension, associated with the structure of the project: The usefulness of the organization of the project by phases in conjunction with the divergent and convergent characteristic of the phases.
- Metaproject Dimension, associated with the organization and communication: Most of the authors do not consider it as a fundamental part of the project, but as a complementary dimension, though not basic.
- Factors Dimension, associated with factors external to the project: The environment is recognized as an influential system in the project, although the classification of the constituting systems of the environment are not evident.
- Techniques Dimension, associated with project methods and methodologies: Proposals and technique analysis as tools of structured knowledge available to the planner and for particular moments in the development the project.
- Tools Dimension, associated with elements or physical support systems: It is not considered a different dimension and supports techniques.

**Table 1. Comparison of different Models considering Gomez-Senent's Intrinsic Dimensions**

| | **Process Dimension** | **Phases Dimension** |
|---|---|---|
| **Jones Model, 1978** | Intellectual activities<br>Problem subdivision | Organization by phases.<br>Divergence and Convergence |
| **Suh Model, 1990** | Solving problems Process<br>Evolutionary and iterative process | Organization by phases.<br>Three phases: Previous, conceptual and detailed |
| **Pugh Model, 1991** | N.A. | Organization by phases.<br>Phases are the central activity. |
| **Palh and Beitz Model, 1995** | Solving problems Process<br>Intellectual activities | Organization by phases and related sub-phases<br>Three phases: Previous, conceptual and detailed |
| **Hubka and Eder Model, 1996** | Mental abilities<br>Process Information of Transformation.<br>Solving problems Process<br>Hierarchical systemic and iterative process<br>Design Science. Transition from the descriptive to the normative. | Organization by phases.<br>It classifies two types of phases. |
| **Cross Model, 1998** | Problem Division in subproblems.<br>Evolutionary characteristics. | Organization by related phases and sub-phases<br>Organization from the problem to the solution |

Based on the analysis it can be said that it is not clear the awareness of the multi-dimensional integration of the project and the complementarity of the six dimensions. Design is recognized as a problem-solving process that requires the intellectual capabilities of the designer, but the influence of environment and management of the project is weakly worked. Classical theories emphasize the morphological composition of the project along with the methods and techniques associated with each phase.

**Table 2. Comparison of different Models considering Gomez-Senent's Extrinsic Dimensions**

| | Metaproject Dimension | Factors Dimension | Techniques Dimension | Tools Dimension |
|---|---|---|---|---|
| **Jones Model, 1978** | It recognizes communication between actors. | It recognizes Context influence. | Structured Knowledge. The Memory extension. | N.A |
| **Suh Model, 1990** | N.A | It recognizes Context influence. | Mathematical Tools. Control Theory in Design. | Computer tools, and software. |
| **Pugh Model, 1991** | Multidisciplinary role. Constant flow of information | The market, the main influence factor. | Pertinent Technical Selection | Computer software Aid |
| **Palh and Beitz Model, 1995** | N.A | Importance of the context in some parts of the project. | Systematic Tools. | N.A |
| **Hubka and Eder Model, 1996** | Design Management .. Connection of Knowledge Areas | It depends of science and technological development. | Structure. Methods and resources of the design .. | N.A |
| **Cross Model, 1998** | N.A | It recognizes the market and other aspects. | Tools of The Knowledge. Association with the phases. | N.A |

## 4. Current work and trends in Product Design considering the Factors and Metaproject Dimensions

At the present time, many of the works related to product design are considering aspects associated with the context where the user and the designer are included. Besides, there is a debate about the project organization, regarding the multidisciplinary composition of project teams, the internal communication processes and the project administration. Both elements mentioned, the context and the project orgaization, are related to the Factors and Metaproject Dimensions within Gomez-Senent's proposed model, respectively.

### 4.1 Analysis of current trends in Product Design which consider the Factors Dimension

Gomez-Senent [1998] proposes under his multidimensional model, the Factors Dimension as the different intellectual activities involved in the process of product development aimed to acquire an overview and a perspective of the external aspects that affect either partially or globally the project . He proposes three main factors: the economic factor, the technological factor and the human factor of which derive many others like quality, functionality, aesthetics, and so on. During the literature review several research trends were found which are associated with different factors in product design and are mentioned below.

First of all, there is the evolution from the technological point of view of product development to a point of view focused on the human being through concepts such as the User-Centered Design (UCD), Interactive Design and Usability, among others. The studies considered both physical-psychological characteristics (perception and cognition) of users and the conditions of use and ease of use of products [Rubin, 1994; Suwaa et al., 1998; Jordan, 2000; Naville et al., 2005]. The analyses make clear the kind of cognitive, emotional and behavioral responses consumers have regarding the stimuli of products [Petitota and Yannou, 2004; Crilly et al., 2004, Norman, 2005]. Also, there are theoretical

and methodological reflections considering the evolutionary characteristic of the product similar to the evolution of nature, with the selectivity and improvement of species principles [Vajna et al., 2005].

Second, there is the development of methods and methodologies to obtain measurable information about qualitative factors (perceptions, emotions) of the product to establish relationships with the configurative properties of the product [Shutte, 2002; Kleff et al., 2005; Chang et al., 2006]. Among them: Expert systems and connectionist systems in order to make more accurate the product creation process [Shutte, 2002; Yanagisawa and Fukuda, 2004; Jaio et al., 2006]; fuzzy models for customizing the product as well as for the configurable design based on the customers' wishes and the product components [Deciu et al., 2005]; Robust Design, Axiomatic Design, and TRIZ, the first to optimize manufacturing and value the customer's voice, the second one, for the convergence of the design process and the third for the promotion of creativity with TRIZ [Dickinson, 2006].

Third, there is present the acknowledgement of the impact of the economic aspects in the context. In this regard, studies on innovation show the importance of the relationship between the University,the State and the Enterprise along with technology, territory and the organization to generate products with a high social benefit that affects positively the different actors and environments [Leydesdorff et al., 2006].

### 4.2 Analysis and current trends in Product Design which consider the Metaproject Dimension

The Metaproject Dimension correlates all systems involved in the resolution of a project from the human point of view. Here, the importance of the human-organisational systems, knowledge systems and physical systems is highlighted. In this dimension, communication, coordination and planning strategies of the project team are involved, as well as aspects of implementation and monitoring.

The current literature addresses the Metaproject dimension in several respects. One of them is associated with the organization of human structures with its communication and coordination within the multidisplinary work. Multidisciplinary work is seen as one of the best alternatives to tackle the projects but some authors are aware of the lack of empirical studies that validate its merits, in scientific research an activity has been found among various disciplines to appropriate their methods, rather than a collaborative work of disciplines [Rafols and Meyer, 2006]. The advantages of the multidisciplinary work are offset by the results from the indirect obtained bibliometric analysis. Recent empirical studies confirm the importance of the communication process and of the cooperative decision-making in all phases of the product design process and not just in the initial stages of problem solving in order to achieve successful results [Miranda et al, 2007] .

Another aspect of current research work is associated with the designers. There is a tendency to strengthen the design teams that change from an isolated designer [monodesigner] to a project team, and the presence of the user during all the design process. The product design evolves from the monodesigner with extensive knowledge [Suh, 1991] to the design team with the presence of experts [Pappalardo, 2006] and the use of mixed techniques in the design process from the Design and the Manufacturing [Fagestrom et al ., 2002; Sahlin, 2000, Arcidiacono et al, 2006]. Within the Axiomatic Design [Suh, 1991], in recent work about the collaboration and negotiation, importance is given to teamwork when it is oriented towards the achievement of the project goal. However, unlike other studies mentioned, Suh's proposal has a very technical approach, since it considers outside from the project those aspects associated with the behavior of the individuals that make up the project team [Suh, 2006].

A final aspect is the temporary nature of the organizational structures of projects. The project, within which the product design is found, is seen as a temporary organization with its own qualities. Organizations that develop projects are evolving into projects that generate organizations known as project-based firms [Blindenbach-Driessen and van der Ende, 2006]. Thus, the project is a temporary organization that transcends the organizational structure and has its own dynamics that prevents it from being worked homogenously using prescriptive methods as suggested by traditional Project Management currents [Packendorf, J., 1995].

### 4.3 Current Status of work in Product Design where Factors and Metaproject Dimensions are simultaneously involved

Among recent work in product design, only one article was found which analyzes the behavior of multidisciplinary teams which has relevance to the Factor and Metaproject Dimension simultaneously [Miranda et al, 2007]. In this study, there are three categories for the analysis of the design teams behavoir: Design creation, planning, and cooperation; the last two are relevant to the Factors and Metaproject Dimensions. The article recognizes, as it has been said in this article, that there is no background in the analysis of the project groups about elements associated with knowledge, skills, attitudes and behaviors of the design of multidisciplinary teams. In its results, the importance of the process is highlighted rather than the design goal which traditionally has been regarded as the essential part in product design. Communication is important during the process and the decision making stages. On the other hand, there are theoric reflections on the involvement of the University and the Industry that promote teamwork project from communities of practice that are conducive to innovation [Fontana et al, 2006; Leydesdorff et al., 2006; Garraway, 2006 ; Yorke and Knight, 2006] but also critical of the loss of identity by the University when working, thinking only in the market [Hayrinene-Alestato and Peltola, 2006]. One of the arguments for promoting these partnerships is that there is no separation of science, politics, culture and industry but that these are interrelated as suggested in the multidimensional model.

Therefore, it can be said that no decided work has been identified on product design which considerers Factors and Metaproject Dimensions simultaneously. Empirical studies are required in order to analyze the planning, implementation and control processes in product design with multidisciplinary and multiorganizational teams which involve for example, the university, enterprise and users, from early stages of the design process. Contributions in concurrent engineering can be associated in a better way to the Phases, Techniques and Tools Dimensions in the activity coordination among various actors from the design to the manufacturing, but does not appear to be directed to performance analysis of a multidisciplinary work that transcends the functional organization of the company. Moreover, the conceptual contributions in areas such as the importance of teamwork, the role of human relationships in the effectiveness of teamwork and the importance of the communication process can not be found in the literature of product design but is observed from the frontier of the innovation, administration and psychology fields.

## 5. Conclusions

It has been found, based on a comparative analysis of the classical theories of design and the multidimensional Gomez-Senent model, that the Metaproject and Factors dimensions are weakly worked in the classical models of product design. The Factors Dimension refers to the intellectual activities aimed at acquiring a comprehensive overview of all aspects that affect the project. Key factors are the technological, the human and the economical factors. The Metaproject Dimension refers to all intellectual activities aimed to correlate all systems that affect the resolution of the project from the human point of view, such as communication, coordination and strategy planning, programming, implementation and control of those involved in the project.

Contributions have been identified in the Factors Dimension as in the Metraproject Dimension, but more empirical work is required for the latter. Current contributions in the Factors Dimension include studies on the evolution from a technological development of products to a point of view focused on the human being, development of methods and methodologies to obtain measurable information of the qualitative aspects of the product as contribution to the configurative properties and also reflections on the impact of the economic aspects of the context in the new possibilities of innovative projects. In the Metaproject Dimension, current contributions are presented in early analysis of organization of human structures, with its communication and coordination within the multidisciplinary work, tendency to strengthen the design teams that change from an isolated designer [monodesigner] to a project team along with the user throughout the whole process and finally, the analysis of the temporality of the organizational structures of projects that require new interaction mechanisms within the organization.

This analysis has enabled to identify possibilities of empirical research of the work of multiorganizational and multidisciplinary design teams so that their behaviors, risks, costs, effective collaboration and design quality can be assessed, and the work in methods of emotional and sensory perceptual evaluation of the product together with its relationship with the product configuration parameters.

**References**


*Aoussat. A. Et al., "The new product design - a transverse approach," Journal of Engineering Design, Vol. 11 No. 4, 2000, pp 399-417.*

*Arcidiacono, G. Et al., "A new management process to analyse the automotive components," Proceedings of Fourth International Conference on Axiomatic Design, ICAD, Firence, 2006, pp 1-5.*

*Blindenbach-Driessen, F. And Van der Ende, J., "Innovation in project-based firms: The context dependency of success factors, "Research Policy Vol 35, issue 4, 2006, pp 545-561.*

*Cappetti, N., "Design decoupling method based on logics for-complete", Proceedings of Third International Conference on Design Axiomatic, Seoul, 2004, pp 1-8.*

*N. Crilly, James M. And P.J. Clarkson. "Seeing things: Consumer response to the visual domain in product design. " Design Studies. Vol. 25. 2004. pp. 547-577*

*Cross, N. "Engineering Design Methods", Editorial John Wiley & Sons, 1998.*

*Deciu, F. et al., "Configurable product design using multiple fuzzy models", Journal of Engineering Design, Vol. 16, Issue 2, 2005, pp 209-235.*

*Desmet, P. "Designing Emotions". Bélgica. 2002.*

*Dickinson, A., "Integrating Axiomatic Design into a Design For Six Sigma Deployment", Proceedings of Fourth International Conference on Axiomatic Design, ICAD, Firenze, 2006, pp 1-6.*

*Fagestrom, J. et al., "Multi-Viewpoint Modeling of the Innovation System - Using a Hermeneutic Method", Proceedings of Second International Conference on Axiomatic Design, ICAD, Cambridge, MA, 2002, pp. 1-11.*

*Garraway, J., "Creating productive interactions between work and the academy.", Higher Education Vol. 52, 2006, pp 446-464.*

*Gómez-Senent E. M. "La Ciencia de la Creación de lo Artificial", Editorial Universidad Politécnica de Valencia, 1998.*

*Jones, J.C. "Métodos de Diseño", Editorial Gustavo Gili, Barcelona, 1978 [2da ed. 1992]*

*Jordan, P. W. "Designing Pleasurable Products". Ed Taylor and Francis. 2000.*

*Kleeff, Ellen van, Hans C.M. van T., P. Luning. "Consumer research in the early stages of new product development: a critical review of methods and techniques". Food Quality and Preference 16, 2005.*

*Lai Hsin-Hsi, Yang-Cheng Lin, Chung-Hsing Yeh, Chien-Hung Wei. "User-oriented design for the optimal combination on product design". International Journal Production Economics 100.. 2006. pp. 253-267*

*Leydesdorff, L. et al., "Measuring the knowledge of an economy in terms of triple-helix relations among technology, organization and territory", Journal of Engineering Design. Vol. 13, 2006, pp. 205-214.*

*Miranda, P et al., "The development of a design behaviour questionaire for multidisciplinary teams", Design Studies, Vol. 28, Issue 6, November 2007, pp 623-643.*

*Naddeo, A., "Axiomatic framework applied to Industrial Design Problem formulated by para-complete logics approach: the power of decoupling on Optimization-Problem solving", Proceedings of Fourth International Conference on Axiomatic Design, ICAD, Firenze, 2006, pp 1-8.*

*Nakao, M. et al., "Axiomatic design based analysis or articles on unmarketable commodities", Proceedings of Fourth International Conference on Axiomatic Design, ICAD, Firenze, 2006, pp 1-7.*

*Norman, D.A. "El Diseño Emocional: Por que nos gustan [o no] los objetos cotidianos". Editorial Paidos. Barcelona. 2005*

*Packendorf, J., "Inquiring into the temporary organization: new directions for project management research", Scandinavian Journal of Mangment. Vol 11, No. 4, 1995, pp 319-333.*

*Pahl, G. and Beitz, W. "Engineering Design: A Systematic Approach", Ed. Springer, 1995*

*Pappalardo, M., "Fusion of Belief in Axiomatic Design", Proceedings of Fourth International Conference on Axiomatic Design, ICAD, Firenze, 2006, pp 1-5.*

*Pugh, S. "Total Design", Addison-Wesley, Wokingham, 1991.*

*Rafols, I. and Meyer, M., "Knowledge-sourcing strategies for cross-disciplinarity in bionanotechnology", SPRU Electronic Working Paper Series. University of Sussex, 2006, pp. 1-18.*

*Sahlin, M., "A Systematic Approach for Decision Making in a Concurrent Engineering Environment", Proceedings of First International Conference on Axiomatic Design, ICAD, Cambridge MA, 2000, pp 35-41.*
*Schifferstein H.N.J. y Marc P.H.D. Cleiren. "Capturing product experiences: a split-modality approach". Acta Psychologica. Vol. 118. 2005. pp. 293-318.*
*Schifferstein, H.N.J. "The perceived important of sensory modalities in product usage: A study of self-reports". Acta Psychologica. Vol. 121. 2006. pp. 41-64.*
*Schütte, S. "Tesis Diseñando Sentimientos en los Productos. Integración de la metodología Kansei al diseño de Productos". Instituto de Tecnología Linkopings Universitet. 2002.*
*Soderlund, J., "On the broadening scope of the research on projects: a review and a model for analysis", International Journal of Project Management, Volume 22, Issue 8, November 2004, pp 655-667.*
*Suh, N., "Application of Axiomatic Design to engineering collaboration and negotiation", Proceedings of Fourth International Conference on Axiomatic Design, ICAD, Firenze, 2006, pp 1-11.*
*Suwaa M., T. Purcella and J. Geroa. "Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions". Design Studies. Vol. 19. 1998. pp. 455-483.*
*Vajna, S. et al., "The Autogenetic Design Theory: an evolutionary view of design process", Journal of Engineering Design, Vol. 16 No. 4, Aug2005, pp 423-440*

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