Co-evolution of design methods and CSCWD systems to improve the preliminary design process

CONFERE 2012 VENISE
5 – 6 JUILLET 2012, SAN SERVOLO, VENISE

CO-EVOLUTION OF DESIGN METHODS AND CSCWD SYSTEMS TO IMPROVE THE PRELIMINARY DESIGN PROCESS

Andrea Luigi GUERRA[1], Thierry GIDEL[2], Enrico VEZZETTI[3], Atman KENDIRA[4]

[1] Université de Technologie de Compiègne, EA 223 Costech - andrea.guerra@utc.fr
[2] Université de Technologie de Compiègne, EA 223 Costech - thierry.gidel@utc.fr
[3] Politecnico di Torino, DIGEP – enrico.vezzetti@polito.it
[4] Université de Technologie de Compiègne, EA 223 Costech - atman.kendira@utc.fr

ABSTRACT
The Preliminary Design Phase (PDP) is the one with the greatest impact on the product development process. Different preliminary design methods have been proposed in order to facilitate and guide the work of design teams during this phase. However, we have noticed that none of these methods have been ideated for Computer Supported Cooperative Work in Design (CSCWD) systems. We think that we can't simply adapt an existing method to these interactive multi-users systems, but that methods will evolve due to the influence of these systems and these systems will be more and more adapted to support preliminary design methods, resembling mutually influencing co-evolution. In section 1 we will present a literature review about the three main subjects concerned by this article: Engineering Design and its methodologies, Preliminary Design and its issues, and CSCWD. In section 2 our research questions and the associated key issues will be proposed together with our hypothesis, then in section 3 our ideas about the research methods will be shown to finally conclude in section 4 with discussion and perspectives.

Keywords: Preliminary Design Methodologies, Product Innovation Management, Computer Supported Cooperative Work in Design, Design Research Methods, Open Innovation.

1 INTRODUCTION
Design is an interplay between what we want to achieve and how we want to achieve it [Suh, 2001].
It involves numerous actors and tools; it requires different and numerous competences. We can imagine it as a process that evolves from abstract (what) to concrete (how), from initial idea(s) to product launch.
We consider for our purposes a branch of Design: Engineering Design.The Engineering Design process is a formulation of a plan or scheme to assist an engineer in creating a product. The Engineering Design is defined as: "…the process of devising a system, component, or process to meet desired needs. It is a decision making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective [Ertas and Jones, 1996]. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation." [Penny, 1970] A clear visual representation of this concept has been proposed by Dixon [Dixon, 1966].
Several authors have proposed their methodologies or strategy for the Engineering Design such as Pahl et Beitz [Pahl, 1999], Suh [Suh, 2001], Hatchuel and Weil [Hatchuel, 2002], Ullman [Ullman, 2003], Ulrich and Eppinger [Ulrich, 2004], et al.
Particularly we want to study a branch of Engineering Design: the Product Design. Product Design is the process of creating a new product to be sold by a business to its customers. It is the efficient and effective generation and development of ideas through a process that leads to new products [Koberg, 1991]. A good Product Design process model is proposed by Riley [Riley, 2012] with five phases

composing the generic product development process: Concept Development, System-level Design, Detail Design, Testing and Refinement, Production Ramp-Up.
We will focus our interest on the Concept Development Phase, also known as Preliminary Design Phase (PDP). The PDP is dedicated creating and classifying new ideas: design teams explore the space of possible solutions, framing the design problem and clarifying user requirements.
We focus on PDP for two reasons: first of all it is the richest phase for what concern the creation of know-how, second because it is the phase that has the greatest impact on the efficiency of the development process[Scaravetti, 2004] [Ullman, 2004]. As MacLeamy's curve show [MacLeamy, 2004], the level of influence of design choices decreases as the project move forward in time , and the cost of the implementation of these choices increases.

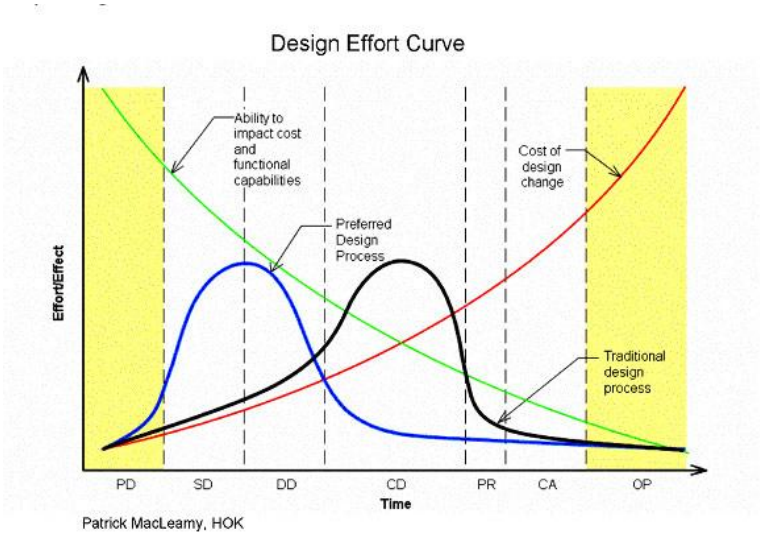

Figure 1. The figure shows how the cost of design change increases during the advancement of the project, while the ability to impact functional capabilities decreases

The collaborative work in the preliminary design phase usually involves a core team formed by 6 to 8 people (where one has the role of the animator/moderator). During the PDP, individual work is performed and specific meetings are carried out, usually around a table and/or a board. This collaborative work takes the form of working sessions where team's members create and manipulate intermediary representation objects. These objects can be grouped in two families: intermediary state of product representation (sketches, prototypes, mock-ups …) [Darses, 1997] and intermediary state of project representation (concepts, functions, planning, risks, ideas...) [Shen, 2002] [Gidel, 2005].
An animator/moderator leads alternating phases of divergence and convergence [Millier, 1997] [Millier, 2002]. During the divergent phase there is individual production and collective work that represent the expansive moments, while during the convergent phase, negotiation and decision-making take place, being moment of focus and concealing. This way of working relies on the expertise and the memory of the participants; they refer to previous projects, state-of-art, competitors, etc.
Many tools can be used in the PDP, like value analysis, causal analysis, risk analysis, creativity techniques, etc. Most of them are extensively described in literature [Rinderle, 1990] [Jones, 1992]. Some tools simply present and structure available information, while others either help producing more information by using simulation or creativity techniques or supporting complex methods or special data management systems.
From our literature review we noticed that the manipulation of intermediary objects is often limited to 2D representation on paper or a screen. The knowledge production is usually on paper support (post-it, paper-board).When software is used, they are usually designed for a single user [Dietz, 2001] [Forlines, 2008]. Sometimes, it is the animator/moderator, who conducts the meeting, which uses the software, sometimes a secretary is needed to type-in the data during or after the meeting, and the most part of software able to trait them is designed for a single user.
Collaborative computer systems, described as "system that supports distal communication between designers" [Kvan, 2000] have been introduced to support embodiment design (CAD systems). The issues to deal with, during the design of CAD systems, are mainly the behaviours, the specifications

and the interactions [Pederson, 1993] [Shiba, 1995]. It is possible to have an idea of a good design process of this kind of systems in MemTable [Hunter 2009].
A particular field of application, for these systems is Design, creating Computer Supported Cooperative Work in Design systems [Grudin, 1994]. For our purpose, as stated before, we will focus on the PDP also because neither visualization nor manipulation of physical prototypes is required and the objects that will be manipulated are merely concepts [Yannou, 2001] allowing participants to collaborate, independently of the personal skill level [Millier 2002].
To our knowledge, there are no preliminary design methods adapted for either CSCWD systems or effective tools [Wang, 2000]
The TATIN PIC Project of the University of Technology of Compiègne has the goal to improve the advancement in this field. TATIN-PIC is a CSCWD composed by an interactive multi-touch tabletop and an interactive multi-touch board, and personal devices such as tablets and smartphones. [Jones, 2011]

Figure 2. The TATIN-PIC: a CSCWD System

2. THE PRELIMINARY DESIGN PROCESS AND CSCDW SYSTEMS

The problematic whe are investigating can be summarized with the following question: "How should the currents preliminary design methods and CSCDW systems co-evolve to augment the performances of the preliminary design process itself?" To answer this question we have to consider two key issues: the proposition of a preliminary design methodology and the description of the use of design tools on and around CSCDW system during the preliminary design process.
Our idea is that the preliminary design process evolves from abstract to concrete by a continuous sequence of divergent and convergent phases [Millier 1997] as well as the parallel but asynchronous evolution of problem and solution [Dorst, 2001] [McDonnell, 2009].
However from our literature review results, we think that until now all the attention has been given either to the single user activity or to the abstract process in its entirety.We lack of descriptions and models about how team members shift from single activity to group activity and from ideas creation phases to synthesis phases.We lack also of a theory that supports the concepts that a design team driven by an animator should explore, on a CSCDW system, different strategies, tools and methods in order to choose the most suitable for the current preliminary design task.
We propose that the phases composing the preliminary design process are divided by milestones [Nihtila, 1999]. Milestones are the logical moment where a synthesis is done, normally with management: some concepts are validated and a new expansive phase begins. Two milestones can normally identify a logical unit of the preliminary design process such as "user requirements definition". Ideally a single logical phase of convergence-divergence can be represented as in fig. 3

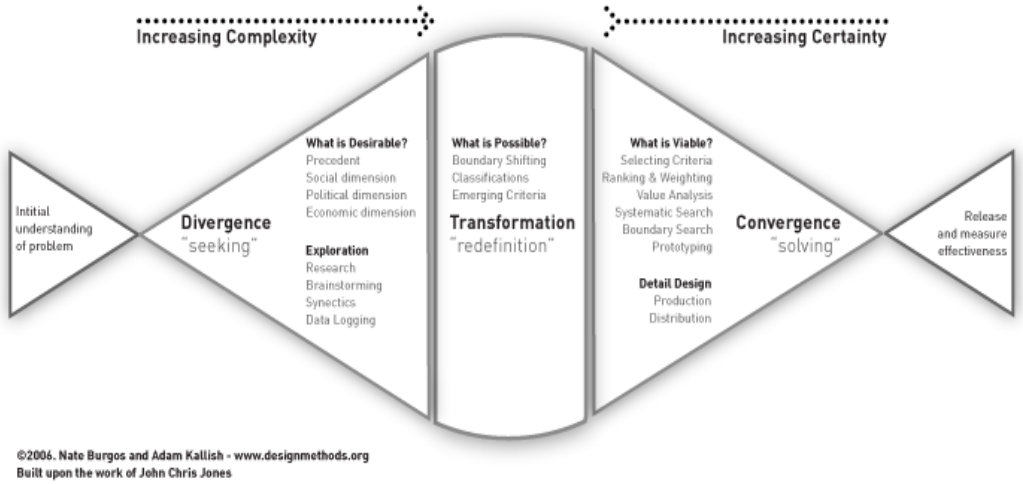

Figure 3. Activities between two milestones [Burgos, 2006]

However we propose to go further and to try to see the evolution of the design process in its entirety, that's why inside this logical unit we will have recursive level of milestones that identify sub-tasks during different design meetings, a single design meeting or a fraction of a single design meeting. From figure 3 we should evolve to a model as in fig. 4

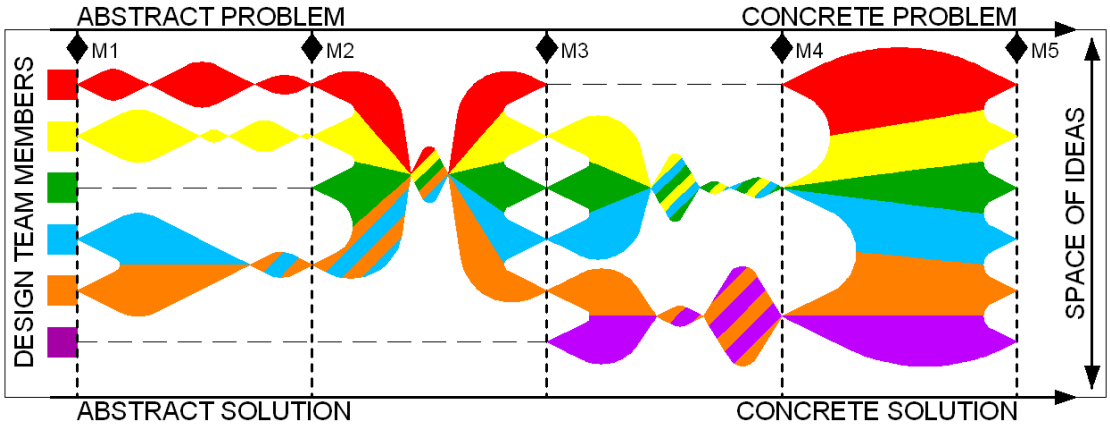

Figure 4. The preliminary design process conceptual model

During the process described in fig. 4 design team members may shift and work with different percentages depending on their roles and competences accordingly to the given task. They may work on the system for collaborative design and produce individually ideas and elements that will be shared during the collaborative meetings as well as stored and capitalized on the system.
What we want to point out is that this vision of the evolution of design process is the most suitable for CSCWD system such as TATIN-PIC. With its horizontal interactive table TATIN PIC can support the collaborative creativity phase (e.g. a brainstorming) and the individual divergent phase (e.g. the work done by the single designer abroad) due to the interoperability between personal devices and the system. The vertical interactive board can support synthesis conducted by the animator and the consequent decision making process of the management thanks to a shared vision and a more filtered access at the board content (the animator is the only one who summarizes) with respect to the table.
Until now we have described a logical model, our vision for the preliminary design phase, but how should the actors involved in the PDP proceed practically?
The method we propose is an evolution of Focused Creativity first proposed by Gidel and Romon [Gidel, 2009]. For that reason we agree that in order to sustain this particular strategy the system should be seen as a toolbox, where designers can explore the solution and the problem space [Dorst,2001] shifting between tools and methods, in a sort of methodological circulation [Gidel,2009]. Due to the fact that design problem are more and more complex and ill-defined [Pirita, 2000] we should allow design teams to progress in several directions as the same time, granting the possibility to study different possible paths between two logical milestones.
As we have described we have a wide range of tools that can be used to support the PDP. All those tools are potentially interesting and more or less suitable according to the nature of the problem and the team members' expertise [Fernze-Walch 2006]. We start from five basic tools actually under implementation: brainstorming, risk analysis, chronograms, cause analysis and functional analysis.
However, in the toolbox at the base of methodological circulation we have to consider also all the ecosystem (people's know-how, networking, databases, etc...) around the research centre, the company or any other subject that will use this system.
This toolbox will co-evolve as well as the design methodology and the system itself, being influenced and influencing the other stakeholders involved in the project.
These two hypotheses open several key issues to take in consideration. First of all, we have to define a clear metric to measure the design performances in order to verify the eventual improvements of the preliminary collaborative design process [Shiba, 1995], [Neely, 2005].
These metrics will be also useful to make a comparison between design tasks done digitally on the tools of the CSCWD system and the equivalent done on paper. Then we have to find evidences of the relations between the horizontal table and the vertical one related to the design phases, for what concerns time of use, shifting between each other, associations with the different activities of the PDP.

Moreover, we will have to consider how the space where the CSCWD system is used will affect the PDP as indirectly suggested by Donald Norman et al. [Norman, 2004] and how the studied design methods will be perceived and used by designers.
Also, the design team will influence and be influenced by the system and the methodology used, so we have to account all the aspects about team composition and roles [Williams, 2010] and to pay attention to the difference between cooperation and collaboration when we analyse the dynamic of the design meetings and the cognitive feedback that the system give to users, so how users represent and perceive the system in their minds.
But the major challenge is the complexity behind this approach. We can't simply try to measure and solve one problem after another due to the fact they are all deeply related. We may find, for example that the dichotomy between horizontal table, vertical board is not the best for the system structure; the following changes will affect all the other key issues. For this reason we will apply an enactive design thinking approach during our research, effectively learning by doing.
In this paper, we don't investigate the data model related problems for interoperability and data representation.

3 RESEARCH METHODOLOGY

To corroborate our findings and intuitions we have to conduct test and experimentations. We decided to split this activity in two different approaches: laboratory users' tests and the follow of an industrial project case study.

3.1 User tests

This approach details a single design session in order to gain insight on the events between two milestones. To achieve this task we will start from the protocol described in [Coldefy, 2007] and [McDonnell, 2009]. Being at the beginning of this research work, we haven't defined all the three years experimentation protocol but some points are already clear.
These experiments will include 8 groups of 6 people composed by students of the UTC aged from 20 to 27 most likely and personnel from the university aged from 25 to 60. Those groups will have a control condition session an experimental condition. They will be filmed, audio recorded, and interviewed at the beginning and at the end of each test session. They will have to simulate a single design meeting or a part of it. They may be challenged in one of the five tools firstly proposed on the table: brainstorming, risk analysis, chronograms, cause analysis and functional analysis.
We will use an approach really close to the one described in [Gidel, 2011], the experimentation room will look like figure 5.
The main goal of this type of tests is to provide evidences to influence the design methodology definition and the evolution of the system itself. Thank to the data that will be collected, we hope to be able to propose a working prototype of CSCWD system specifically conceived for the preliminary design phase, in order to test it with industrial partner all along the preliminary design phase and not just atomically between two milestones.

Figure 5.Example of the design research methodology[Gidel, 2011]

3.2 Industrial projects case studies

To have a clearer idea on how the preliminary design process evolves over time we will conduct also tests using the living lab paradigm [Følstad, 2008].

Both University of Technology of Compiègne and Polytechnic of Turin have innovation centre facilities where enterprises can meet universities. We imagine proposing at our industrial partners to develop a project on the TATIN PIC system for what concerns the preliminary design phase.

This strategy will allow us to have an overview all along the preliminary design process, not just between two milestones and to have feedbacks directly from the future users of our methodology and system. This kind of approach is really important also for the analysis of design team composition, interaction between users and system, and the management of the roles inside design teams.

Practically, we think to install the system in a space inside an innovation centre like facility, where periodically mixed design team (university and enterprise) will meet to develop a new product.

Then, we will record and analyse the meetings as described in 3.1

Following, a user centered design approach [ISO 9241-210:2010] and by using evaluation phases, we aim to have feedback from user to correct the possible bias between our theoretical model and practical needs and to first present an analysis all along the PDP proving our hypothesis about the development of the preliminary design process, the most suitable tools, and the relationship between design team and CSCWD systems.

4 DISCUSSION AND CONCLUSIONS

We think that we can propose a new preliminary design methodology adapted for CSCWD system such as TATIN-PIC, particularly focusing on the dichotomy convergence-divergence and the co-evolution of problem-solution based on the Design Thinking Theory, providing new insights on the preliminary design methods for CSCWD system.

This new preliminary design methodology will hopefully augment the performance of design teams and CSCWD system during the preliminary design phase, increasing the capabilities and the possibilities of the design teams themselves.

We will define and implement the concept of "methodological circulation" firstly proposed by Gidel and Romon, through the analysis and the implementation of a collection of tools. A new data model adapted to the context will be necessary in order to support the methodological circulation.

We will improve also the know-how on the design of a CSCWD system, the TATIN-PIC, with insights and new ideas on user-machine interactions, collaborative spaces structureand its cognitive implication on users.

This will grant us insight to better understand the difference between co-operation and collaboration and to further advance in the subject of co-evolution in the design process [McDonnell, 2009].

For our purpose, as detailed in section 3, we will have to define new design research methods or to adapt existing ones, increasing the know-how in the field, for example with benchmarking among digitalized tools and paper based tools. This will lead to a further research into new metrics for benchmarking and for evaluating the performance of the design process that could be re-used by others.

Finally, we will test this system in an Innovation Centre, based on the Open Innovation (OI) paradigm [Chesbrough, 2003]. Through a Living Lab approach[1], especially focusing on Small Medium Enterprises (SME), we may contribute with the proposition of new OI scenarios, which preview the use of the TATIN-PIC as a facilitator, for the concrete implementation of an Open Innovation strategy. The evidences may be useful to answer to the third and the fourth question posed by Gassman [Gassman, 2010] concerning SME and spatial location of Open Innovation activities.

[1] http://www.openlivinglabs.eu/

REFERENCE

[1] Chesbrough H. (2003) The Era of Open Innovation. In *MIT Sloan Management Review*

[2] Codelfy F., Louis dit Picard S. (2007) DigiTable: An Interactive Multiusers Table for Collocated and Remote Collaboration Enabling Remote Gesture Visualization. In *IEEE International Workshop on Projector-Camera Systems*

[3] Darses F. (1997) L'ingénierie concourante: un modèle en meilleure adéquation avec les processus cognitifs de conception. In *ingénierie concourante, de la technique au social* (Economica, Paris) pp. 39-55

[4] Dietz P., Leigh D. (2001) DiamondTouch: a multi-user touch technology. In *Proceedings of UIST' 01*

[5] Dixon J.R. (1966) *Design Engineering* (McGraw-Hill, New York)

[6] Dorst K. (2001) Creativity in the design process: co-evolution of problem-solution. In *Design Studies* vol.22 (5) pp. 425-437

[7] Ertas A. & Jones J. (1996). *The Engineering DesignProcess 2nd ed*. (John Wiley & Sons, New York).

[8] Fernez-Walch S., Romon F. (2006) *Le management de l'innovation. De la stratégie aux projets* (Vuibert, Paris)

[9] Følstad A. (2008) Living Labs for innovation and development of information and communication technology: a literature review. *In The Electronic Journal for Virtual Organizations and Networks*, vol. 10 (August) , pp. 99-131

[10] Forlines C., Lilien R. (2008) Adapting a single user, single display molecular visualization application for use in a multi user, multi display environment. In *AVI '08: Proceedings of the working conference on Advanced Visual interfaces*, ACM Press

[11] Gassmann O., Enkel E., Chesbrough H. (2010) The future of Open Innovation. In *R&DManagement* (Blackwell, Oxford)

[12] Gidel T., Gautier R., Duchamp R. (2005) Decision-making framework methodology – An original approach to project risk management in new product design. In *Journal of Engineering Design*, vol. 16, pp. 1-23

[13] Gidel T., Kendira A., Jones A., Lenne D., Barthès J.P. , Moulin C. (2011) Conducting preliminary design around an interactive tabletop. In *Proceedings of ICED'11*

[14] Gidel T., Romon F. (2009) Dedicated Collaborative Space opened to all opportunities but focused on innovative target. The UTC innovation centre case. In *Proceedings of DDPI '09*

[15] Grudin J. (1994) Computer-Supported Cooperative Work: History and Focus. In *Computer* vol.27(5) pp. 19-26

[16] Hatchuel A., Weil B. (2002). La théorie C-K: Fondements et usages d'une théorie unifiée de la conception, *Colloque Sciences de la conception*

[17] Hunter S. (2009) MemTable, Contextual Memory in Group Workspaces, *Master Thesis, MIT MediaLab*

[18] Jones A. (2011) The TATIN-PIC project: a multi-modal collaborative work environment for preliminary design. In *CSCDW '11 Proceedings*

[19] Jones C.J. (1992) *Design Methods* (Wiley, Hoboken)

[20] Koberg J. , Bagnell J (1991) *The universal traveller: A soft system guide to creativity, problem-solving and the process of reaching goals* (W. Kaufmann, New York)

[21] MacLeamy P. (2004) Collaboration, integrated information and the project lifecycle in building design, construction and operation. In *The Construction User Roundtable*

[22] McDonnell J., Lloyd P. (2009) *About: Designing. Analysing Design Meeting* (Francis & Taylor, London)

[23] Millier P. (1997) *Stratégie et marketing de l'innovation technologique* (Dunod, Paris)
[24] Millier P. (2002) *L'études des marches qui n'existent pas encore* (Editions d'Organisations, Paris
[25] Neely A., Gregory M. Platts K. (2005) Performance measurement system design: a literature review and research agenda. In *International Journal of Operations & Production Management,* vol. 25 (12) pp. 1228-1263
[26] Nihtila J., (1999) R&D-Production integration in the early phases of new product development process. In *Journal of Engineering and Technological Management,* vol. 16, pp.55-81
[27] Norman D. (2004) *Emotional Design: Why We Love (or Hate) Everyday Things*(Basic Books, New York)
[28] Pahl G., Beitz W., Schulz HJ., Jarecki U. (1999) *Engineering Design: A systematic approach 3rd ed.,* (Springer-Verlag, London)
[29] Pederson E., McCall K., Moran T., Halasz F. (1993) Tivoli: an electronic whiteboard for informal workgroup meeting. In *InterCHI '93*
[30] Penny R.K. (1970) Principles of engineering design. In *Postgraduate Medical Journal,* Vol. 46, pp. 344-349.
[31] Pirita S. (2000) Weaving Design Process as a Dual space Search. *In Department of Home Economics and Craft Science Research Reports 6. University of Helsinki.*
[32] Riley R.Q. Enterprises (2012) http://www.rqriley.com/pro-dev.htm
[33] Rinderle J. ,Hoover P. (1990) Function and form relationships: strategies for preliminary design, *Carnegie Mellon University Engineering Design Research Centre, Paper 16*
[34] Scaravetti D. (2004) Formalisation préalable d'un problème de conception, pour l'aide à la décision en conception préliminaire. *Thèse de doctorat en Mécanique, Ecole Nationale Supérieur d'Arts et Métier,* Bordeaux
[35] Shen C. , Lesh N. , Vernier F. , Forlines C. ,Frost J. (2002) Sharing and building digital group histories. In *CSCWD '02: Proceedings of the 2002 ACM conference on Computer-Supported Cooperative Work*
[36] Shiba S. (1995) *Les outils de management de la qualité* (MFQ éditions, Nanterre)
[37] Suh N.P. (2001). *Axiomatic Design: Advances and Applications* (Oxford University Press, Oxford)
[38] Ullman D. (2003) *The mechanical design process 3rd ed.* (McGraw Hill, New York)
[39] Ullrich K, Eppinger T.(2004), *Product Design and Development 3rd ed.* (McGraw Hill, New York)
[40] Wang L., Shen W., Xie H., Neelamkavil J., Pardasani A., (2000) Collaborative conceptual design – state of art and future trends. In *Computer-Aided Design* vol. 34 (13) pp. 981-996
[41] Williams, H. M., Parker, S. K. and Turner, N. (2010) Proactively performing teams: The role of work design, transformational leadership, and team composition. In J*ournal of Occupational and Organizational Psychology*, vol. 83, pp. 301–324.
[42] Yannou B. (2001) Préconception de produits. *Mémoire d'habilitation à diriger des Recherches, Institut National Polytechnique de Grenoble,* Grenoble