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### ► To cite this version:

Andrea Luigi Guerra, Thierry Gidel, Enrico Vezzetti, Atman Kendira. Co-Evolution of Design Methods and CSCWD Systems to Improve the Preliminary Design Process. Co-Evolution of Design Methods and CSCWD Systems to Improve the Preliminary Design Process, 2012, San Servolo Venice, Italy. pp.8. ⟨hal-04466760⟩

**HAL Id: hal-04466760**

**<https://hal.science/hal-04466760v1>**

Submitted on 27 Jan 2026

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

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## ABSTRACT

The Preliminary Design Process (PDP) has a great impact on the product development process. However, there is a lack of Computer Supported Cooperative Work in Design (CSCWD) systems and associated methods to support and improve the work of the design team members during PDP. In this paper after a literature review of PDP methods, we identify the key elements that should be taken into account to improve the PDP through the use of a CSCWD system. We expose our hypothesis: the use of a CSCWD system, supported by a proper PDP model and a specific ontology, can augment the collaboration and the creativity (number and quality of concepts generated) of the design teams and so improve the performances of the PDP itself.

We then present our research project and explain why design methods and CSCWD system should evolve jointly in order to improve the PDP. We suggest to follow an enactive and design-thinking approach to reach this goal. We propose a first theoretical model describing the preliminary design process. The paper concludes with some considerations about the related key issues and the possible implementations and benefits.

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

## 1 INTRODUCTION

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.

### 1.1 Engineering Design and Product Design

Design is an interplay between what we want to achieve and how we want to achieve it [Suh, 2001].

We consider for our purposes that engineering design is defined as "...the process of designing a system, component, or process to meet desired needs. It is a decision making process (often iterative) ..." [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]. Several authors have proposed methodologies or strategies for engineering design such as Pahl and Beitz [Pahl, 1999], Suh [Suh, 2001], Hatchuel and Weil [Hatchuel, 2002], Ullman [Ullman, 2003], Ulrich and Eppinger [Ulrich, 2004]. Based on those methods and starting from Zimmer works [Zimmer, 2001], Scaravetti [Scaravetti, 2004] proposes a generic product development process: Conceptual Design, Detail Design, Development.

## **1.2 Preliminary Design Process PDP**

We focus on the Conceptual Design Phase where the Preliminary Design Process (PDP) takes place [Scaravetti, 2004]. The PDP is dedicated to problem identification, creating, evaluating and classifying new concepts: the design teams alternatively reformulate the brief and explore the space of possible solutions, framing the design problem and clarifying requirements. PDP 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].

Our focus is on PDP for two main reasons: first it is a strategic phase because of the key decisions that have to be made with very little information available, second it has a great financial impact because most of the future costs of the project and of the product depend on the decisions made at this stage [Ullman, 2004] [MacLeamy, 2004].

### **1.2.1 Collaborative Work in PDP**

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 project manager/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 and data. These objects can be grouped in two families: intermediary state of product representation (concepts, functions, sketches, prototypes, mock-ups ...) [Darses, 1997] and intermediary state of project representation (planning, risks, resources, costs ...) [Shen, 2002] [Gidel, 2005]. During PDP visualization and manipulation of physical prototypes is still quite rare. Objects that are manipulated are mainly concepts [Yannou, 2001], allowing participants to collaborate, independently of the personal skill level [Millier, 2002].

The project manager/moderator leads alternating phases of divergence and convergence [Millier, 1997, 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 converging.

### **1.2.2 Tools and methods in PDP**

Many tools and methods are used during 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. The knowledge production is often on paper support (post-it, paper-board).

## **1.3 Computer Supported Collaborative Work in Design**

Collaborative computer systems, described as "system that supports distal communication between designers" [Kvan, 2000] have been initially introduced to support embodiment design (CAD systems). Our interest is focused on collaborative interactive multiuser multimodal systems dedicated to preliminary design. From our literature review we noticed that today those CSCWD systems [Grudin, 1994] allows the manipulation of intermediary objects, often limited to 2D representation on a screen. Softwares are usually designed for a single user [Dietz, 2001] [Forlines, 2008]. Sometimes, it is the project manager/moderator, who conducts the meeting using the software; sometimes a secretary is needed to type-in the data during or after the meeting. To our knowledge, there are no preliminary design methods suitable for implementation on a CSCWD systems nor effective softwares able to support efficiently the collaborative work of design team members during the preliminary design process [Wang, 2000].

The goal of our research is to improve both the PDP methods and the CSCWD systems. For that purpose the University of Technology of Compiègne as developed the TATIN-PIC CSCWD system (Figure 1) [Jones, 2011].

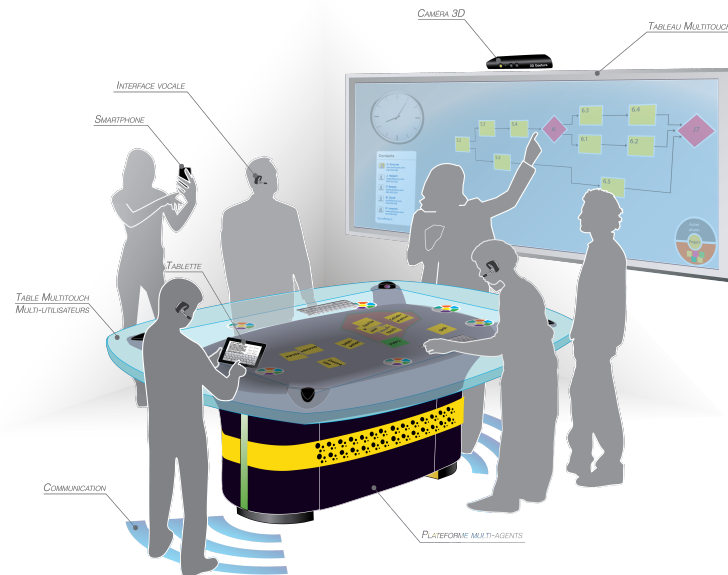


Figure 1. TATIN-PIC platform: an interactive tabletop, an interactive board, tablet-PC's, smartphone and headsets.

## 2. CO-EVOLUTION OF DESIGN METHODS AND CSCWD SYSTEMS

Our research question is: “How should the current preliminary design methods and CSCWD systems co-evolve to augment the performances of the preliminary design process itself?” To answer this question we have to consider two major issues: the preliminary design model and the CSCWD system during the whole preliminary design process (not only during the meetings but also taking into account individual work between meetings).

We formulate the hypothesis that the use of a CSCWD system, supported by a proper PDP model and a specific ontology, can augment the collaboration and the creativity (number and quality of concepts generated) of the design teams and so improve the performances of the PDP itself.

This is possible only under certain conditions:

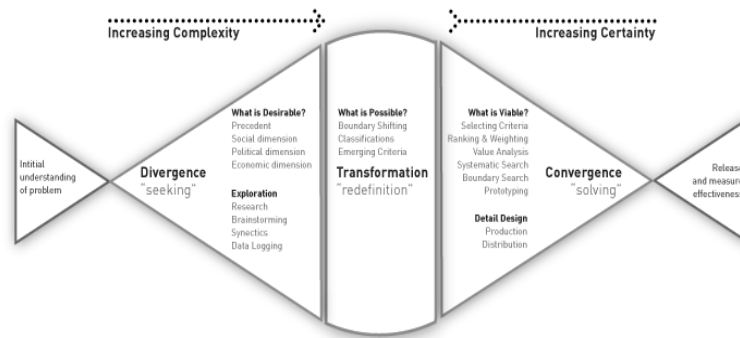
1. The PDP model must clearly respect the vision of co-evolution of solution and problem through a continuous sequence of divergent and convergent phases (where all solutions can be explored) done both as a single/subgroup activity and a collective activity.
2. The physical conformation of the CSCWD system and its stage must support this dualism between divergent phase and convergent phase. They must be “affordant” for the design team cognitive perception [Lerdahl, 2001]
3. The design team must dispose of a toolbox of preliminary design methodologies and related tools [§1.2.2] adapted for a CSCWD system. The system must leave the project manager free to choose the appropriate tools according to the situation.
4. The CSCDW system must support the shift among the different tools in a transparent manner for the users thanks to a multi-agent system and a proper ontology [Xie, 2010]
5. The PDP model, and the related ontology, should support the shift between single/sub-group activity work and collective work, during the PDP, as well as the interoperability from the data produced during these heterogeneous phases.

### 2.1 General model of the preliminary design process evolution

Meetings where collective work is carried out divide the steps composing the preliminary design process. Between meetings, individual work is performed to prepare the decision process. It is during meetings, usually with management, that decisions are made. We use milestones [Nihtila, 1999] to represent and define the moments where a meeting takes place.

At a macro level, a divergence-convergence phase (figure 2), starts from the initial understanding of the problem, passing through the definition and exploration of the desiderata (increasing the problem complexity) to arrive at a point where divergence stops. From this point all the ideas generated are

filtered by choosing what idea is viable and possible converging toward a solution (increasing the solution certainty). This process can be represented as in fig. 3.



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Figure 2. Activities between two meetings [Jones, 1992]

We propose to go further and to try to model the evolution of the preliminary design process in its entirety. At a micro level, we will have recursive or fractal divergent-convergent phases both at individual and group level. We should try to identify and support sub-tasks during and between design meetings. Those sub-tasks could be divergent or convergent, individual or group work. From figure 2 we should evolve to a model as in figure 3.

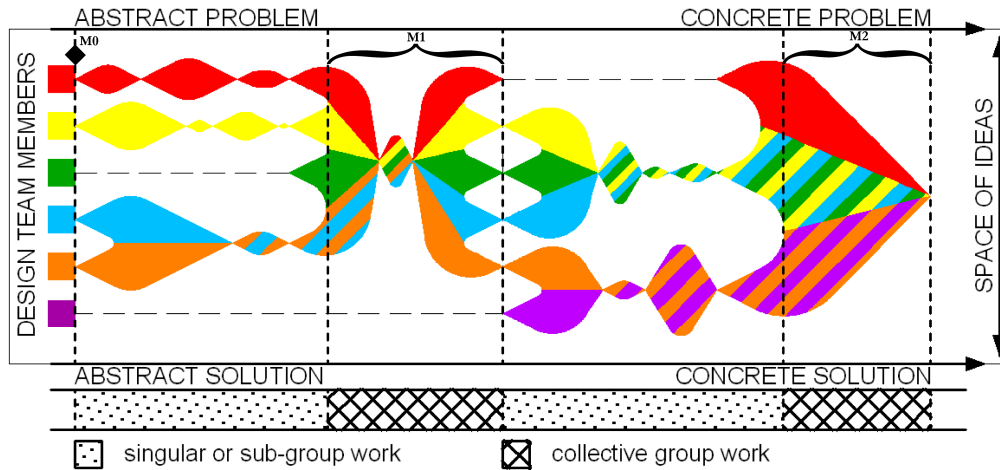


Figure 3. The preliminary design process conceptual model

During the process described in fig. 3, individual work is done by some members such as red and yellow between milestones 0-1. Some members could also collaborate between milestones such as blue and orange member. Also, some experts do not participate in some phase such as purple and green member. During meetings, individual points of view are shared through different medias and data and decisions are produced, stored and capitalized. During the preliminary design process, we may have phases (e.g. collective group work after M1) where a previous focalization leads to a wider generation of new concepts, which is typical of a design thinking approach.

This design process model seems the most suitable for CSCWD system such as TATIN-PIC. The horizontal interactive tabletop would support the collaborative divergent phase (e.g. concept generation), the vertical interactive board would support the collaborative convergent, synthesis phase (e.g. concept evaluation) and due to improved interoperability, personal devices such as smart phones and tablets would support both divergent-convergent individual work.

## 2.2 Methodological circulation: a suitable approach to support the PDP work

The method we propose is an evolution of the focused creativity first proposed by Gidel and Romon [Gidel, 2009]. 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 methodological circulation [Gidel, 2009]. Due to the fact that design problems are more and more complex and ill-defined [Pirita,

2000] we should allow design teams to progress in several directions at the same time, granting the possibility to study different possible paths between two logical milestones.

A wide range of tools can be used to support the PDP. All those tools are potentially interesting and suitable depending on the nature of the problem and the team members' expertise [Fernez-Walch 2006]. To start, five basic tools are actually under implementation on TATIN-PIC platform: brainstorming, logigrams/chronograms, risk analysis, causal analysis and functional analysis. We also have to consider all the ecosystem (people's know-how, networking, databases, etc...) around the design project. Therefore, access to databases and Internet is facilitated.

This toolbox will co-evolve together with the design methodology and the system itself, being influenced and influencing the other stakeholders involved in the project.

### 2.3 Key issues and challenges

We lack descriptions and models about how team members shift from single activity to group activity and from divergent/creative phases to convergent/synthesis phases. Especially, we lack models that could be implemented on a CSCWD system. One of the difficulties is to elaborate a model that facilitates the design of a CSCWD system that allows the project manager and his team to choose its own strategy, tools and methods. The project manager and his team should also be able to change their mind as the design process evolves.

Our hypothesis and the related conditions 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 CSCWD system and the equivalent done on paper. Then we have to find evidences of the added value and relations between the horizontal tabletop and the vertical board during design process.

The design team will influence and will be influenced by the CSCWD system and the methodology used. We have to take into account 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 gives to users, so how users represent and perceive the system in their minds.

## 3 RESEARCH METHODOLOGY

We will conduct test and experimentations. We wish to split this activity in two different approaches: laboratory users' experimentation and industrial project case study.

### 3.1 User tests

This approach details a single design session in order to gain insight on the events during and between two meetings. To achieve this task we will base our approach on the protocol described in [Coldefy, 2007], [Buisine, 2012] and [McDonnell, 2009]. Being at the beginning of this research work, we haven't detailed the experimentation protocol but some points are already identified.



Figure 4. Example of the design research methodology [Gidel, 2011]

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 and 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 conduct part of a

design process using some of the five tools proposed on the table: brainstorming, risk analysis, chronograms, cause analysis and functional analysis. We will ensure that comparison could be made with previous experiment described in [Gidel, 2011] see figure 4. The goal of these tests are to validate the model and provide evidences of the impact of CSCWD system on preliminary design.

### 3.2 Industrial projects case studies

We will also conduct tests using the living lab paradigm [Følstad, 2008]. Both University of Technology of Compiègne and Polytechnic of Turin have innovation centre facilities where companies can conduct design projects. We will propose to our industrial partners to develop a project on the TATIN-PIC system. This will allow us to have an overview all along the preliminary design process, and have feedbacks directly from the future users of our methodology and system. 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 present an analysis of the PDP.

## 4 CONCLUSIONS

A new preliminary design methodology adapted to CSCWD system such as TATIN-PIC, particularly focusing on the 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 is needed.

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

The “methodological circulation” approached will be implemented on the CSCWD system. A new data model adapted to the context will be necessary in order to support this “methodological circulation”. We want 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].

We will test this CSCWD system in an Innovation Centre, based on the Open Innovation (OI) paradigm [Chesbrough, 2003]. Through a Living Lab approach<sup>1</sup>, 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.

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