An approach to modelling the dynamics of the design process in architecture

Ah. Laaroussi & A. Zarli
CSTB. 290 route des Lucioles – BP 209, 06904 Sophia-Antipolis cedex, France

J.C. Bignon
CRAI UMR MAP. Culture/CNRS, N°694. 2, rue Bastien Lepage, 54001 Nancy cedex, France

ABSTRACT: This study presents a brainstorming on the dynamics of the design process in architecture. It is motivated by the needs and the evolution of the professional practice, and based on their study; it is exposed to allow us to learn the appropriate lessons for a future modeling of this dynamics. We will introduce our working hypothesis of the component dynamics and suggest a model for dynamics of design process in architecture.

1INTRODUCTION

Design is a complex activity and the design process lies within scientific, social, economic and cultural context at the same time.

If the first objective of a design process is still to define an answer to an unsatisfied need, design in architecture underlies a targeted objective, represented in most cases by an object to be conceived, more or less accurate in its initial definition. The evolution of the designed object is sequenced by a whole set of stages and phases, not necessarily linear, and consequently tends to some degrees of certainty which are not absolute.

Either we are mentioning a large or a small realization, any operation of construction is characterized by *temporary associations* of complementary skills. The aim of the actors is the achievement of the project, but with *not very explicit* and *poorly codified* practices. Limited by *the unicity* of the projects, these practices are a logical consequence of the diversity of actors, documents and stages of the design - realization process, large amount and diversity of the daily practices.

On the other hand, if we consider the design process in architecture as a continuous input flow (e.g. addition of a document, arrival of a new actor, creation of a task...) and an outgoing flow (e.g. end of a task, removal of a document…), we can compare it to a systemic process which tends to an evolutionary open system. The objective of such a system is the "*constructability"* of the architectural project in design.

This concept of dynamics, governing all data of the architectural project according to the stages of formalization, deserves to be explored and analyzed in order to satisfy a need of traceability and legibility of the design process in architecture.

In the same way, the transverse organization of the design in architecture – better corresponding to the structure of the architectural project - and "confrontation" among actors of different professions Castelfranchi (2000), outline the issue of responsibility and are leading to new activities and new interface trades. Thus, we can guarantee the transparency of the design process as well as the memory of the project.

This article initiates some questions we are trying to answer by presenting our approach and our scientific step of development in the third section of this communication. These questions are as follows:

- How to model this open and non fixed system in time?
- What content has to be modeled?

2STATE OF THE ART ON THE DESIGN IN ARCHITECTURE

This section presents a brief state of the art on our research subject. It focuses on the points which lead us to formulate our research hypothesis.

2.1 *The collective and shared natures of the design from Co-design to distributed design.*

In practice, most of design activities combine various contributions made by different actors. In the construction industry, Callon (1997) displayed this collective and negotiated nature. With the architect, responsible for the architectural design, several engineers specialized in various technical fields (e.g. structure, acoustics, thermics…) take part in the design of the building, on the basis of specifications defined by the client. The execution studies that consist of setting up methods of building construction and are carried out by the contractors, are becoming more and more important in the building design.

As described by (Darses & Falzon 1996, Turk et al 1997, Hanser 2003) the implication of actors in a design process can take various forms. Their engagement in the process is similar to a Co-design or a distributed design (Figure 1). The actors can meet these two situations successively, during the same project or the same design process.

Thus, at engaging meetings or at definition of requirements, it is in the dynamics of Co-design that makes the whole group work together. The actors develop a joint solution. They share an identical goal, which is to define a requirement of solution to achieve the expressed objective. All these actors use specific skills but with strong collective constraint to attain a common goal: *the choice of a requirement of solution*.

The choice of principles marks the beginning of structuring the future works, the actors are no more jointly but simultaneously implied into the process. Then they are going to work on specific tasks, related to their specific skills. We are close to the concept of the *distributed design* here.

These actors strive towards their own aims and objectives, while taking part as effectively as possible in the collective definition of work.

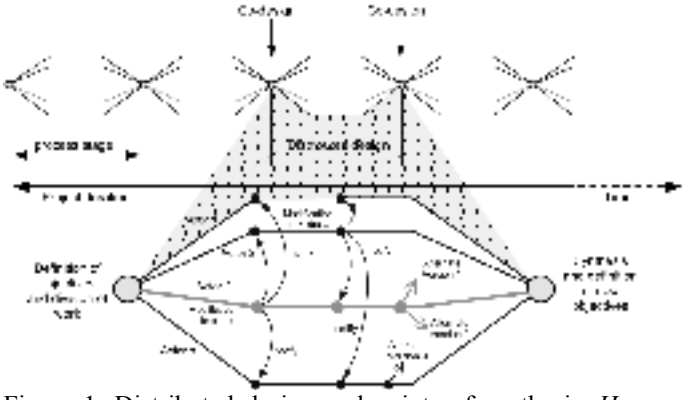

Figure 1. Distributed design and points of synthesis. *Hanser*, (2003) according to (*Turk* et Al. 1997)

2.2*Design process from divergent angles*

The design process has been researched by various scientists from different points of view. On having carried out a deep analysis of their works, we would like to present the results they have received under four dimensions: communication, organization having an influence on communication, cognitive aspect of design process and planning of design activity.

First, it is important to notice that many scientists pay our attention to the complex nature of the dynamics in the design process and underline the existence of various reasons that have their influence on it. However, they do not define composing dynamics and leave the question of their formalizing open to discussions.

It is also necessary to add that the analysis of the dynamics of the design process is rarely a key factor of the works we have analyzed. While presenting a model, the authors mark its importance; still the implication of the proposed models can be hardly provided "in pertinent changes of distributed environment" Chiu (2002).

The role of organisation in design communication and collaboration is studied in "An organizational view of design communication in design collaboration" Chiu (2002). The author presents a process model of design collaboration that is supposed to be facilitated by a structural organization and a computer-supported collaborative work. Having a project-oriented character, the architectural design practice is well described by design organisation and design activities.

While speaking on communication problems in design collaboration, the scientist underlines the dynamic character of media, semantic, performance and organizational aspects and their influence on design collaboration of the whole project. The particular attention is put to the information flows in design communication, the participation of individuals in each task and the coordination of design information. The author also tends to illustrate his approach by case studies and design experiments.

As for the cognitive aspects of the model of Chiu, the article gives a basic understanding of the design collaboration in the architectural practice and formulates the main principles of design strategies. The author underlines the importance of three levels of communication (individual, group, project) but he leaves a reader to formalise differences between these levels as well as to seek supplementary mechanisms for the direct application of one model in the design process in architecture.

The interdependence between the communication factor and the cognitive approach in design is presented by Stempfle & Badke-Schaub (2002). The authors introduce four basic cognitive operations of designed research that establish a generic model of design team activity – generation, exploration, comparison and selection. They focus on the analysis of main cognitive operations of the design process –

generation and exploration, which are followed by mechanisms of its natural evolution – blind variation and selective retention. Methods of comparison and selection are chosen to narrow the problem space and to detail the basic elements of thinking in design teams. The proposed approach enables the decomposition of the team-design process that gives the possibility for planning in the terms of content- and process-directed activity.

The authors propose a parallel analysis of the activities directed towards the content of a design problem and of those directed towards the organisation of the group process.

The general character of the model is explained by the chosen analysis (analyse of frequencies, process analysis under a macro/micro perspective). This scientific viewpoint limits its industrial implementation: "design methodology has not been as readily accepted in industry as design methodologists have expected". It is also important that the model is not particularly made for architecture, but it seems to be rather flexible for modelling interactions which form the base of the dynamics.

The cognitive approach is well described in the other article by Chiu (2002). The article proposes a descriptive model of the situated design detailed by a design experiment, case adaptation and comparative analysis of the design situations.

A research paradigm of case-based reasoning and main principles of design moves are taken into account in the analysis of the designed situatedness – the situated activity of the interaction among "*designers, cases, programmes, individual workplaces and tools*" Chiu, (2002). The observations and the analysis of their results are proved by a design experiment from the point of view of various participants. We find it essential to underline that the model describes low-level interactions. That is why the learning ability of situation identification and case adaptation of the model could be hardly applied for the complex process of design in architecture.

Mao-Lin Chiu also proposes to apply constructive memory of cases and design tools of the model for future development planning of suitable computational environment for designers. The model establishes the relation between the behaviour of designers in new situations and the routine design process.

On the other hand, the metrics based analysis model (Xijuan et al. 2002), reflects the general approach of the design process. The scientists propose a mathematical model of process planning that provides high design performance within a limited schedule and budget. They conduct an effective task analysis on optimizing the process of design organization measured by different degrees of task importance. Starting by task decomposition and computing the critical degree of each task, the authors receive an evaluation of the likelihood of error occurrence for each task-contributing factor. The total degree of the task importance is found by adding its spread degree that reflects the interdependence of all factors. Therefore, the task analysis model forms a base of the design process planning followed by the evaluation of results.

The classification of the factors into critical and non-critical is made after the cognitive analysis of a full-scale and open-architect database of design process systems. However, this subjectivity and lack of the possibilities to manage and control the design process turn out to be disadvantages of the approach.

Speaking on the design in architecture, we require a more flexible model that would represent the dynamics of the process and illustrate its "architectural" characteristics.

2.3 *Conclusion of the state of art*

In short, previous studies have focused on issues of design collaboration including the process, the team works, the design settings groupware, the organization teams; and they influence on communication patterns. However, these studies rarely focus on the importance of the whole dynamics of design process in architecture. The following sections will present our brainstorming on the dynamics of the design process in architecture and our model suggestion.

3SUGGESTED APPROACH AND SCIENTIFIC STEP OF DEVELOPMENT

In fact, social, temporal, and cognitive contexts play a considerable role in the evolution of an architectural project. These contexts cannot be taken into account in such a structured approach of the design. Therefore, it is important to consider the design in architecture not only as an activity of resolution of issues, but also as a complex activity, that has to reckon technical, temporal, social, strategic and economical aspects at the same time.

The design process in architecture can be compared to "a living being" having continuous input flows (e.g. adding a document, arrival of a new actor, creation of a project …) and output flows (e.g. end of a task, deletion of a document…). So, we notice the existence of input and output data which have to be defined and validated. In that way we progress the design process in its every identified stage. That allows us to speak on a certain generation and destruction of the components that keep this process in a stable state.

Such stability is one of the main criteria of the design process as it guarantees its proper functioning. However, the design process reacts to the temporary changes of the environment and to "stimulus" by the reversible fluctuations of its stable state (e.g. taken into account new legal requirements, administrative and judicial procedures, technical requirements …).

These changes can be regarded as temporary perturbations which convert a "being" into "equilibrium" at the flow equal to the stable state.

The multivarious intern and extern interactions and the dynamic organization of the design process in architecture underline its systemic character; so it turns out to be *an open system* having a goal of *constructability* of the architectural project in design. We can also notice that the design process in architecture is an ordered system of sub-systems in interaction. These sub-systems also constitute a certain order: the represented state on each observation level is just a result of exchanges between the components of lower levels (Figure 2). This order is not a resultant of rigid functionalities of the components; it results essentially the coordinating interactions among the components which roles are not constant.

So, according to its internal and external multivariable interactions and its dynamic organization, the design process in architecture can be compared to *a measurable open system*.

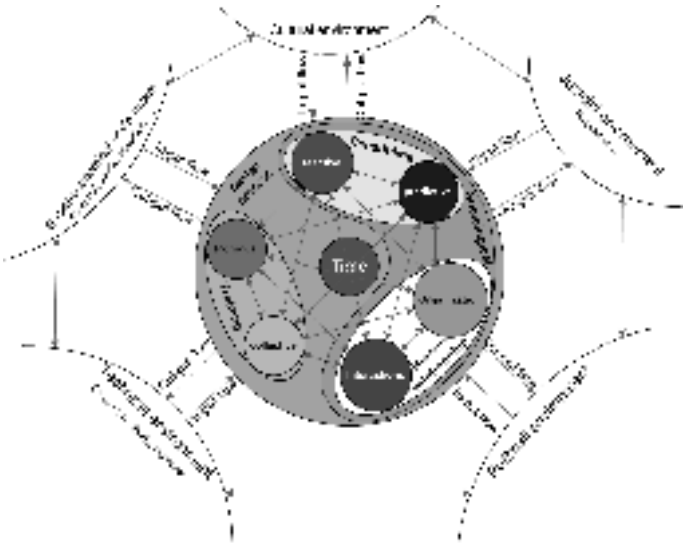

Figure 2. Systemic diagram of the design process in architecture.

We are actually raising a working hypothesis, based on the fact that the design process in architecture is governed by three dynamics: *temporal, sociological and cognitive*. The hypothesis is presented in the next section.

3.1 *The design in architecture: a dynamic process*

Our suggested hypothesis relies on three main dynamics: temporal, sociological and cognitive. These dynamics are explained here after.

3.1.1*A temporal dynamics*

Any actor of the design act has a temporal organization and should respect it. Moreover, s/he is a "wheel" inside a huge temporal mechanism related to the project in design (e.g. identification cycle of issues, phases of design process, delay of expiration…).

One of characteristics of the architectural design is to embrace a great temporal extent made up of various intervals (e.g. phases).

One can thus imagine that the architectural project is an equilibrium among three phases:

- *The time of design:* includes all creation activities, spatialization and adaptation to the standards and to the rulebook.
- *The time of realization:* concerns the implementation of the design and manufacturing elements.
- *The time of memorizing:* is about the upkeep and management assets as well as any communication and storing activity concerning the building.

The various modes of time management, classically used in projects of architecture in design, remain at the lowest level: either at concept of *logical time*, or at concept of *physical time* (Figure 3).

- *Physical (universal) time* is defined by *absolute physical durations* (e.g. hours, days, weeks…) which connect the project to the real world and allow reliable planning.
- *Logical time* indicates the number of *executions cycles* (e.g. phases and stages), sequences of events which a reference to physical time can be allotted to.

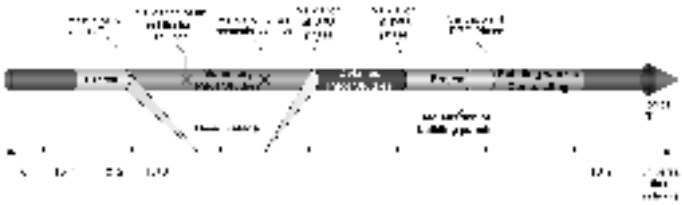

Figure 3. The activity like a bond between the universal time and the logical time.

3.1.2*A sociological dynamics*

The sociological dynamics concerns any transfer or share of skills thanks to perceptions of the indicators coming directly from the immediate environment of the actor or her/his own interpretation of other actors' behavior.

The capacity of these various actors who act jointly on building in design depends on their ability to distribute and justify their interventions. Therefore, one's ability to communicate her/his point of view and to exchange information is extremely essential to an optimizing order of the design process. Thus, the sociological dynamics of the design process in architecture is defined as follows:

- *The interactions between actors* who can be either in *upstream of activity* (e.g. to examine many specifications answers) or *during activity* (e.g. to make sure of the coherences of the solutions, to resolve the conflicts, to cooperate), or in the *post*

activity (e.g. to examine and cure the malfunctioning solutions). The interaction is "*the reciprocal reaction of two phenomena one to the other; moreover, the social interaction is the interpersonal relation between at least two individuals, which behaviors are mutually influenced and consequently change each other.*"[1]. This definition allows us to highlight the concept of reciprocal action and the generic concept of influence Ferber (1996). Indeed, an actor does not carry out an action but he has an influence on it that could be a possible reason of a change of state if it is combined with other simultaneous influences. This influence has a direction which starts from the one who exerts the influence towards the one who receives it. *It is thus said, that there is an interaction, when the behavior of an actor is influenced by others as a result of communication.* Consequently, we characterize the interaction by the communication and its influence. To handle the data on interactions we base our work on the «social networks analysis» Degenne & Forse (1994), Wassermann & Faust (1994) and its techniques (e.g. sociometric analysis, sociograms…). As it follows from the results of the sociometric analysis, it is possible to identify the preferential channels of communication, the most active individuals, the most required interlocutors and the constitution of possible sub-groups. Moreover, the sociogram being a network, it gives the group in interaction an appropriate interpretation in terms of graphs. Thus, based on the "graph theory", we can analyze the dynamics of the relations which continuously affect the group-kind structure. For example, one will seek to precisely evaluate the differences distinguishing two sociograms of the same group that correspond to different moments. Moreover, this approach allows us to evaluate the evolution of the team project cohesion in time.

▪*The organizational tasks aspect:* the design in architecture is an activity that has to *be planned* and instrumented, an activity where the actions to be carried out are defined previously with a regard to the realization of the activity Guerriero (2002). Meanwhile, the design in architecture is an activity that *changes* in time and *fits* to its internal and external environment fluctuations. Its content changes according to the environment and the profil of actors who carry it out. The design in architecture has thus to be planned, but planning does not guarantee the success of the process. Planned once, the design activity does not stop its evolution. So, we can define the design process as *a predictive* and *reactive activity* the same time. The methods of scheduling suggested in the literature (e.g. Pert, Gantt) are multivarious and diversified. We can classify them into two main categories: predictive methods and reactive methods.

Predictive methods make the design process possible in short or long term to carry out scheduling on the basis of estimated data.

Reactive methods make the design process possible to react dynamically taking into account the state of the system and the advance of the tasks. They thus authorize to bear in mind the risks which could threaten the system. A real-time scheduling method can suggest a solution taking into consideration the real state of the system in order to optimize its function. To determine the scheduling dynamics of the design project, we will adopt the method of queues management by rules of priority. We return to Mebarki (1995) for a heuristic state of the art of the scheduling dynamics based on the rules of priority of queues. With regard to this approach, we thus should define rules of priority adapted to our problem.

3.1.3 *A cognitive dynamics*

The actors of various professions, who intervene into the building life cycle, usually have to "build" lots of knowledge and their own know-how. At the same time, the horizontal nature of the design process in architecture requires cooperation.

Baumard (1991) considers the cooperation to be a complex system of knowledge exchange. Its dynamics is based on collective progress. So it is important to assure the transfer of the "frozen" individual knowledge not to be modified during interactions. Moreover, it is also important to include "built" knowledge; the result of the interactions.

Indeed, in the architecture design each actor constructs his own objectives while interacting with other partners. Then actors produce and implement heterogeneous knowledge which is shared among actors through discussions and negotiations.

We can also say that the design activity bases on the mobilization of knowledge distributed and developed by many actors, according to *individual* or *collective training* processes Hatchuel (1994) (Figure 4).

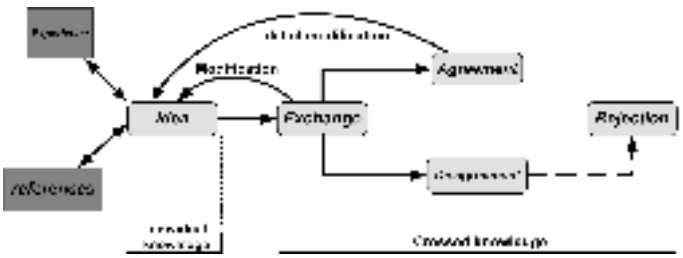

Figure 4. Modes of trainings in the design process in architecture

It is exactly at the cognitive stage that the knowledge should be joined together and coordinated for the proper project development and the design process success.

[1] Larousse Universal encyclopedia. 2002

3.2*Metrology of the dynamics of design process in architecture: suggestion and difficulties*

As our research aims at modeling the dynamic aspect of the design in architecture (open system), it seems essential that we can quantify the metrics of this dynamics in order to reproduce the phenomenon.

On this purpose, we propose a representation of our model in three dimensions (Figure 5) with axes containing units, interval and scale.

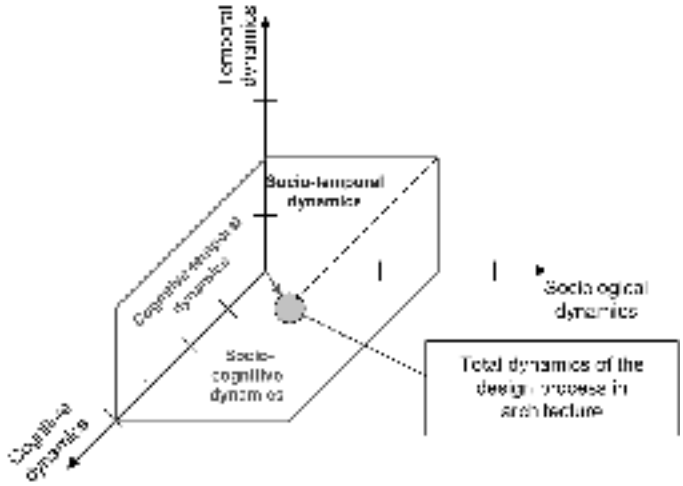

Figure 5. Measurement methodology of the design process in architecture dynamics

The difficulty of our approach lies in the measurement of each dynamics and particularly the sociological and the cognitive ones which are obviously too complex to be represented numerically.

In order to overcome this difficulty, we currently work to define the topological space basis of the design process dynamics. While admitting the topological nature of the space of this dynamics, followed by the characteristics of the Hausdorff topological space Choquet (1992), we will establish a homeomorphism between our model and the Euclidean space. That will allow us to introduce the concept of distance between sub-dynamics. Moreover, we will be able to establish a correspondence between the hyperspace of the dynamics of design process in architecture and sub-spaces of its sub-dynamics. These aspects of work are ongoing and will be further developed in next articles.

4APPLICATION AND BENEFITS OF THE RESEARCH

In order to project our research into the concrete context of the design practice, our plans are to start by checking our hypothesis on the dynamics of the design process in architecture. The aim of this phase is to identify and to formalise the "*vectors*" that have their influence on the design process in architecture development. To achieve this goal, it is anticipated to first interview the practitioners in order to highlight the causes that conduce to the design development. After it, we typify these causes according to our hypothesis (interaction, organization, planning, time, and cognition). At last, each identified cause and its dependences are defined by mathematical functions that will rationalize our approach.

While having this phase ongoing realization, we intend to relay on it in order to formalize our model of the dynamics of the design process in architecture. It can be achieved by the conceptualization of the causes that have been previously defined. As a result of this conceptualization, we will suggest a conceptual model supporting the dynamics of the design process in architecture. After having validated this conceptual model by confronting it to practice, we will implement it into one assistance tool: a *project manager assistant* in design in architecture. Based on the concept of dashboard, the tool will permit the manager to follow the project evolution in time and to maintain the traceability of the process as well as to anticipate problem situations during the conception.

To wrap up, our project manager assistant tool in design in architecture is to answer the following sample of questions:

- Whom did the actor X interact with on Friday, the 11th of February? What was the subject of the interaction? Which tool did he use?
- Did the actor Y answer the actor X? Did he propagate the message of the actor X? If yes, which destination, how?
- Which version of the document was propagated by the actor Y?
- Who quitted the project group on the 14th of February? Who joined the project group? To which consequences for the project group and for the task planning did it lead?
- Which is the network of affinities of the project group at the moment T?
- Which is the social situation of the actor Z in the group of actors or project group? Influential? Indispensable? Driving? Restraining? (…etc).
- What is the new configuration of the group after the actor X has left it?
- What are the dependences of the task X? How should we optimize the planning according to these dependences?
- What does the group of admissible issues of order consist of after the cancellation of the task X? After the departure of the actor Y? After the document Z has been lost?
- What is the learning level generated by the group? (index of leaning)
- What has the project learnt? (Who has learnt? What has been learnt? When was it been learnt?)

5CONCLUSION

To sum up, our brainstorming leads to a rich working hypothesis which allows a new approach enriched by quantitative studies and experimental checking. The applicative objective of our research is to allow the total perception of the design process by the project manager, while giving him an account of its dynamics (concept of dashboard). Thus, the project manager will be able to make the adequate decisions to reach the desired performance. On the other hand, he will have a tool to visualise the state of the system or its sub-systems in any moment of the design process. Moreover, this research will allow to memorize and to analyze the dynamics produced during the process that consequently will influence the future tasks.

ACKNOWLEDGMENT:

The authors would like to thank Anastasiya Yurchyshyna for her participation in this research.

REFERENCES:

Baumard, P .1991. La stratégie de l'entreprise en état de veille – stratégie et surveillance des environnements concurrentiels.

Callon, M. 1997. Le travail de la conception en architecture. Les cahiers de la recherche architecturale (ed), N°37. pages : 25-35

Castelfranchi, C. 2000. Conflict Ontology . In : Müller, H. J. Dieng, R. (Eds). Computational Conflicts, conflict Modeling for Distributed Intelligent Systems. Springer, 2000. pages : 21-40.

Chiu, M.L. 2002. An organizational view of design communication in design collaboration. Design Studies Vol 23. (N°. 2 March 2002): pages 187-210

Choquet, G. 1992. Cours de topologie, espaces topologiques & espaces métriques, fonctions numériques, espaces vectoriels topologiques. Masson (ed). Paris

Darses, F & Falzon, P. 1996. La conception collective : une approche de l'ergonomie cognitive. In Coopération et conception. Sous la direction de G. de Terssac et E. Freidberg Octarès (eds). Toulouse.

Degenne, A. & Forse, M. 1994. Les réseaux sociaux. In collection U, Série Sociologie, Armand Colin (ed). Paris

Ferber, J. 1995. Les systèmes multi-agents, vers une intelligence collective. InterEditions (ed).

Guerriero, A 2002. Etude de la coordination dans la coopération entre acteurs au cours de la conception d'un bâtiment. Mémoire de DEA, Modélisation et Simulation des Espaces Bâtis. Université Henri Poincaré, Nancy. Pages : 23-31

Hanser, D. 2003. Proposition d'un modèle d'auto coordination en situation de conception, application au domaine du bâtiment. Thèse de doctorat en sciences de l'architecture. INPL. Nancy

Hatchuel, A.1994. Apprentissages collectives et activité de conception. Revue Française de gestion, juin – juillet. Pages : 109-120.

Mebarki, N. 1995. Une approche d'ordonnancement temps réel basée sur la sélection dynamique de règles de priorité. Thèse de l'université de Lyon.

Stempfle Joachim. & Badke-Suhaub, Petra.2002. Thinking in design teams – an analysis of team communication. Design Studies. Vol 23. (N°. 5 September 2002): pages 473-496.

Turk, Z. Katranuschkov, R. Amor, R. Hannus, M. Scherer R.J. 1997. Conceptual Modeling of a Concurrent Engineering Environment. Collection Concurrent Engineering in Construction. Institution of Civil Engineers. London.

Wassermann, S. & faust, K. 1994. Social Network Analysis: Methods and Applications. New York: Cambridge University Press.

Xijuan, L. & Yinglin, W. & Shouwei, J. 2002. A metrics based task analysis model for review planning. Design studies Vol 24. (N°. 4 July 2003): pages 375-390