
A formalism for the rationalization of decision-making processes in complex collective design situations

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ABSTRACT

Experimentations with classical Design Rationale formalisms are conclusive in many design situations. However we have encountered a situation where it was impossible to use QOC to represent the argumentations that led to decisions. That failure brought us to elaborate a typology for collective design situations and especially to indentify situations that we have named “complex”. In these situations the modelling has to express temporal evolution of unique solution and roles played by the actors during the collective problem solving process. To memorize the collective design processes in these situations, we suggest the ABRICo formalism that we sucessfully test in the scope of the set up of a Document Management System.

KEYWORDS

Cooperative design, Design Rationale, project management, knowledge engineering, rationalization

1. INTRODUCTION

Since the early 80's, firms have had to face the need for permanent innovation. They have had to find both new products and several versions of a single product to extend their range. In order to encourage this continuous creation, firms reduce their bureaucratic or hierarchic structures to the benefit of transverse and more participative processes that allow people with different competencies to share their knowledge. With these new forms of work, some problems appear, concerning not only the firm's structure but also the dynamics of knowledge that keep it going (Hatchuel, 1992), (Schmidt, 1994).

Indeed, collective work leads to some difficulties or crises as in the case of sharing knowledge among people who do not have similar qualifications. In order to increase effectiveness in the workplace, these crises have to be managed, meaning that knowledge which plays a role in collective work has to be rationalized¹. Hence we have to know how this knowledge is produced, validated, and so on.

¹ "the rationalization trend, which was specialized in productive activities, is now extended to design problems", (Giard, 1996)

Now, the collective problem solving processes through which this knowledge originates takes place in meetings². The main steps in these meetings are decisions, whether they be in themselves the goal of the meeting or enable continued work on a common basis. To rationalize the decision-making processes that give rise to a confrontation between fields of knowledge and make it possible to reach common ground is a good way to rationalize the knowledge arising in collective work.

One way to rationalize these collective decision-making processes is to memorize the line of argument that leads to a decision. This makes it possible, for instance, to table a question, to deal with another one and to go back to the first question without losing the first link in a chain of reasoning. Memorization also makes it possible to save time by reusing some elements of past reasoning, in order to avoid repeating past studies or asking questions previously answered.

Design Rationale methods (Moran, 1996) enable this memorization for design processes. These methods have been developed in software, mechanics, and robotics, where one has to memorize a choice between different features of an artifact (Grudin, 1996). We are going to show that design situations in these areas are *specific* and that there are other kinds of design situations we shall call *complex* and for which classic Design Rationale methods cannot be used.

We are now going to describe what Design Rationale is and particularly one of its formalisms (QOC). We will then define what we shall call complex design situations. Lastly, we will propose, supported by concrete examples, a formalism for the rationalization of design processes in these complex design situations. We will conclude by proposing some future fields of work to complete our approach.

2. WHAT IS DESIGN RATIONALE ?

2.1. Generally

The term "design rationale" is used in many different senses, and no one of them is standard in this stage of research on the topic. We can quote (Moran, 1996) six senses:

- The expression of the reasons for the design of an artifact.
- The logical reasons given to justify a design artifact.
- A representation for recording the logical reasons for a design artifact.
- A method for designing, in which a DR notation is used as a process-facilitation tool for guiding the design process.
- Documentation of the reasons for the design of an artifact, the stages of the design process, and the history of the design and its context.
- An explanation of why a designed artifact (or some feature of an artifact) is the way it is.

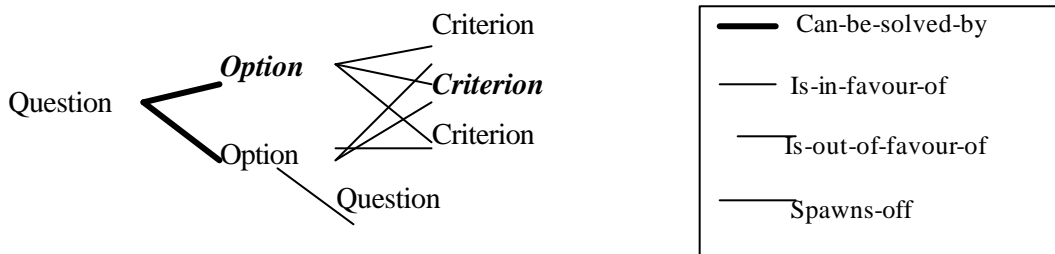
Most of the current research is concerned with the representation of rationale, both its form and content. The aim is to produce a representation that can help others understand why the resulting design is the way it is, and to develop ways of reusing components of the design space to support further design and re-design. The goal is to find the most realistic and the least expensive way to memorize the reasoning, but it has to be structured and clear (Mac Lean, 1989). Therefore, things that have been memorized will be understandable and usable by someone who did not design the artifact and is trying to understand this artifact. Inasmuch as the main activity in meetings is the formulation and criticism of arguments, the Design Rationale goal is to develop schematic representations that will enable computers to support creation, evaluation, and modification of arguments. The main hypothesis is that when one makes the structure of the arguments explicit, the arguments will be built and explained more rigorously. Several methods have been developed.

² The need for studying " periodic co-operation meetings ", has already been stressed by several researchers in CSCW, for instance (Zacklad, 1996)

The difference between these methods is the formalism chosen to represent the arguments, the types of arguments that will be memorized, and the detail level it will be possible to obtain. We can quote DRL (Design Representation Language) (Lee, 1996), IBIS (Issue-Based Information Systems) (Yakemovic, 1993), and QOC (Questions, Options and Criteria) (Mac Lean, 1996). We are now going to describe the last one, developed at the Rank Xerox EuroPARC (Cambridge). It enables one to represent, in a graphic design space, different solutions with their advantages and drawbacks.

2.2. QOC's example :

QOC supports the representation of the design space around an artifact being produced. This design space is an explicit representation of alternative design options, and the reasons for choosing among those options. The figure below shows Questions that highlight key issues in the design space. Options can be thought of as "answers" to Questions. Criteria are the reasons that argue for or against possible Options. We represent relationships between Options and Criteria as relatively positive (solid line between Option and Criterion), or negative (dotted line). Options may spawn off consequent Questions which allow more detailed aspects of the design to be addressed.



Experimentation with the QOC method has been generally conclusive: Some researchers have successfully tested the capacity for the notation to represent a design process and used QOC as a technique for understanding designs through analysis and for characterizing some aspects of design activity (Mac Lean, 1996). In (Karsenty, 1996), the author presents the positive results of an empirical evaluation of DR documents (which were constructed using QOC), carried out with six experienced professional designers who were asked to understand and to assess a past design. The three studies presented in (Schum, 1996-b) and the two in (Schum, 1996-a) are interested in QOC structure as a cognitive tool to support individual and collaborative design in real time. The conclusion is that QOC provides most support when designers need to elaborate poorly understood design spaces in order to clarify the key Questions, Options and Criteria. However, certain difficulties have been identified: In (Schum, 1996-a), we can read difficulties encountered with QOC constructs: Firstly, Questions can be used by posing an extremely general Question or through a long series of Questions, each of them addresses the problem of the current iteration. Whereas, on the one hand, a very general Question offers no insight to someone else trying to understand the design, on the other, many different Questions increase too greatly the number of schemas, and they become unusable. Secondly, discrete Options were sometimes impossible to identify because the design of the final structure was treated as the evolution of one Option over time; the difference between each version was only a single, or a few fine details. Finally, designers sometimes had trouble precisely justifying their preferences for an Option. In the final analysis, the only Criterion they were able to identify was "did it work ?" The difficulty is that for the purposes of QOC, this needs to be reexpressed as more focused Criteria which build a bridge from that goal to specific design features. In the studies presented in (Schum, 1996-b), designers found that sometimes, QOC was intrusive when they were trying to evaluate relatively well understood design spaces in which the main task was to satisfy multiple constraints through iterative testing and adjustment, until an optimal solution has been obtained.

We identified the main characteristics of situations for which it is possible to use existing Design Rationale formalisms:

- If the decision is the result of a choice between different alternatives that have been proposed in the meetings. Take an interface for example: there could be a choice between a narrow or a wide scroll bar, continuously appearing or not.
- If the time available to elaborate solutions is limited: punctual questions are raised and designers answer them in one or two meetings. Hence this time parameter seems inessential and does not appear in classic Design Rationale formalisms.

The actors' role in meetings is an element *not* taken into account in existing formalisms, because in the course of discussion these actors do not necessarily call upon an expertise that would be their own.

But all design situations do not respond to these characteristics. We have identified some situations that we shall call complex whose characteristics are:

- The final decision is constructed progressively and does not result from a choice between different alternatives.
- The time available to elaborate solutions is extended: it may be several months, and time is then a parameter to be taken into account.

The actors' roles are important because their competencies are not interchangeable. Each actor as it were is an expert.

For these situations, it is impossible to use a classic Design Rationale formalism, primarily because these methods do not allow one to retranscribe a solution's progressive evolution during meetings, but only the choice of one alternative among many.

Finally, when several alternatives may be proposed, classic DR formalisms like QOC are workable and are a useful representation of classic decision-making methods such as choosing or sorting out³. In this case, we could object on the one hand that the time over which propositions are elaborated and the order of arguments and criteria formulation do not appear, and on the other hand, that the roles of the actors who bring up issues are not mentioned.

We are now going to study cases where the solution is constructed step by step and where several solutions cannot be compared at once. In these cases, we cannot use existing Design Rationale formalisms. First we are going to identify what these complex situations are, and then we shall propose a way to formalize the discussions that lead to decision-making in these cases.

3. WHAT ARE COMPLEX DESIGN SITUATIONS ?

3.1. Uncertainty

As Hoc has pointed out (Hoc, 1989), problem-solving strategies are different according to knowledge and detail levels. In large design projects, designers face great uncertainty about the features of the solution they will adopt. The knowledge level is low at the beginning of the project. In order to reduce this uncertainty, designers adopt "depth-first" strategies, which lead them to explore the details of a solution, even if it means throwing the whole solution back into question, contrary to "in-breadth-first" design, where they examine several solutions' sketches among which they have to choose. In these complex situations, it is necessary to represent a solution's evolution over the course of a project by virtue of the increased knowledge level, and

³ in (Hoc, 1989), we can read that these situations where one explore simultaneously several solutions (in-breadth-first research), are very costly in terms of work memory.

not the sorting out or the choice among several solutions whose features are known (Giard, 1996)⁴.

3.2. Time

As we have already stressed in introduction, complex design situations last for long periods. Then, it's necessary for the rationalization of the process, to represent the progressive evolution of the solution in dating the different versions in order to restore the "phylogenesis". In some cases, the new propositions are diametrically opposed to the previous ones. In other cases, in contrary, they are a combination of different features of the previous propositions. Because the classical DR formalisms stress the logical relationships between the arguments, they put the elements of the discussion in an "a-temporal" space. So, they do not permit to catch the project dynamics. By introducing this dynamic dimension, we hope that we will give a better comprehension of the solution's evolution which will improve the ability to revise afterwards the solution. So, if some constraints⁵ on the project are modified, it will be possible to identify when these constraints influenced the design, and we will be able to elaborate a new solution starting at this point, without having to reexamine elements of previous decisions.

3.3. Roles

Design Rationale's aim is to represent lines of argument that lead to decision-making in design situations. Thus, in complex situations, the actors can play quite different roles. Take a project meeting for example: we may have the owners who finance the project, the contractors who carry out the project, and among them a project manager, some designers, a quality manager... This diversity has an influence on the progress of design processes. Identifying the role of the actor who formulates an argument enables one to better comprehend the discussion because it allows a new criterion to appear that was not formulated in the meeting. This criterion is the influence of the source formulating an opinion. Indeed, an argument does not have the same weight, or even the same significance, if it is formulated by the project manager, the quality manager, or a designer for example. Classic formalisms of Design Rationale cannot account for one important element of complex design situations which is the roles' *diversity* because roles do not appear in these formalisms. So this will be an element to take into account for a rationalization of the decision-making processes in complex collective design situations.

4. HOW TO ACCOUNT FOR COMPLEXITY, TIME AND ROLES ?

4.1. An example of a complex design situation

We were present at several meetings with the main participants of a market that fits in with a project of France Telecom's research center on software quality. The goal of this market was to put into practice a solution to manage and produce documents and to follow this experimentation at a pilot site. The solution, based on an Document Management System, had to facilitate cooperative work on a common document collection. The contract consisted of four stages. The one that we studied is the first one, whose duration was three months. It was made up of a needs analysis and a modeling. At the end of this stage, the project committee of France Telecom had to decide if it agreed with the propositions and the software tool proposed by the chosen firm.

⁴ "one can say that the difference between a production process and a project process is that the aim of the first one is anticipated at the beginning of the process, when one have to involve in the second one to know if it could be brought to completion, and what will be the conclusion. Let's stress here on the fact that there is also uncertainty about the goal to achieve. The assertion that there is a priori a target does not mean that this target could be precisely and surely defined at the beginning." (Giard, 1996)

⁵ See the graph of the dynamical evolution of knowledge and freedom degrees of a project in (Midler, 1996)

Important decisions on final results were made in meetings⁶, though this was not the declared goal. The discussions were more exchanges of viewpoints on the solution, and there were not really Options to answer a Question and Criteria by which to choose among these Options. For each of the meetings at which we were present, we tried to use QOC but without any success.

4.2. An answer : ABRICo

When we analyze the meetings described above, we can make some observations on the structure and the content. These meetings are made up of progress reports by the supplier and a control and/or a validation by the client. The decisions made are more the result of interactions between different actors in one or more meetings than the result of a sorting out or a choice of a solution after research initiated by a precise demand. In the meetings at which we were present, we have identified a goal to achieve, each party interpreting this goal, identifying functions to implement in order to achieve the goal, and seeking how to implement these functions. We shall now define these concepts and build the models that will describe decision-making processes with these concepts.

The formalism

Common goal: the goal expresses a need to be satisfied. It can be identified by virtue of part of the contract: in this case it is equivalent to an objective to be achieved by one party. The goal can also be the result of an agreement between parties: for example the use of a particular method to solve a problem. This is a common element among the parties; it is the beginning of a work process in which the following categories will be found. A goal might be for example "to elaborate a procedure of needs analysis for producing and archiving documents".

One party's interpretation (op): the interpretation expresses the way in which an actor or a group of actors appropriates the goal and thinks about ways to attain it. It is a function to be implemented in order to achieve the goal. Each party has its own interpretation of the goal, and that's what will lead to discussion. An interpretation might be for example "analyzing work processes".

One party's proposition (op): it is a proposition on how to implement the interpretation. Said interpretation may be that of the party who expresses the proposition or that of another party. In the latter case, the proposition is a reaction that responds to a solicitation from the other party. The proposition consists in showing how it is possible to achieve the functions that allow one to reach the goal. For example, a proposition might be a presentation of schemas.

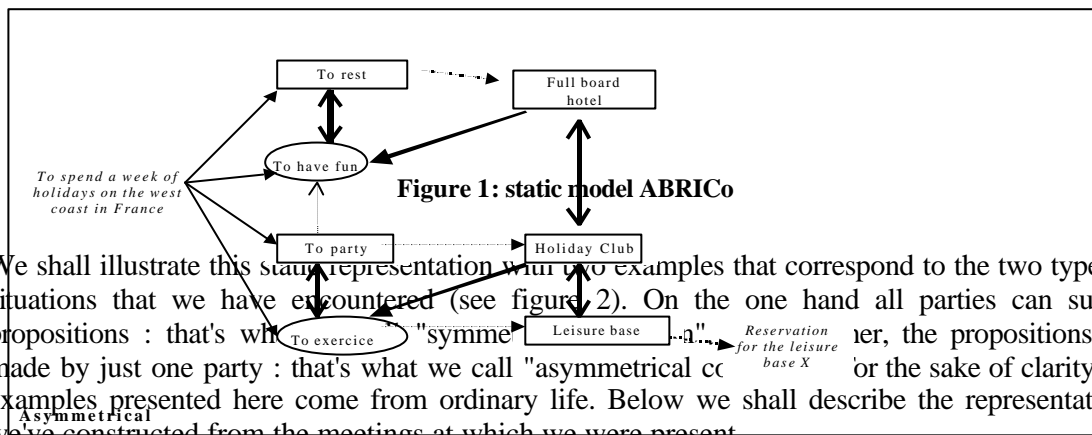
Agreement between the parties (bp): agreement is when a consensus on the proposition(s) is expressed with regard to the interpretation. Hence it is a common element among all the parties, which may occur in the course of the work process and which represents a decision when it closes the process. For example, an agreement might be the acceptance of certain schemas or the decision to use a particular tool.

Starting with the analysis categories presented above, we constructed a static model that identifies the types of links that exist between categories and a dynamic model that shows how they follow on from each other in the course of one or more meetings. These models might represent two situations we encountered in the meetings and that seem to be ones generally encountered where collective work is involved. However we do not claim to be exhaustive and we could be led to enrich our modeling if we encounter a new situation. We have named this modeling ABRICo for

⁶ The actors of the meetings were not always the same but were part of these: For France Telecom, the one in charge of the technique, the expert of Document Management Systems (DMS), the expert of processes and methods, and the users representative. For the supplier, the project leader, the project manager, his assistant, the expert of DMS, and the computing specialist.

the French words Accord (agreement), But (goal), pRoposition, Interpretation en Conception (during design).

In the static model, we show the relationships between the analysis categories, i.e. between goal, interpretation and proposition but also the relationships that might exist between two interpretations or two propositions. This model allows us to complete the definitions of the concepts given above (see figure 1). Applying this model to a decision-making process will allow better comprehension of the structure of this process.



We shall illustrate this static representation with two examples that correspond to the two types of situations that we have encountered (see figure 2). On the one hand all parties can supply propositions : that's what we call "symmetrical" or the sake of clarity, the examples presented here come from ordinary life. Below we shall describe the representations we've constructed from the meetings at which we were present.

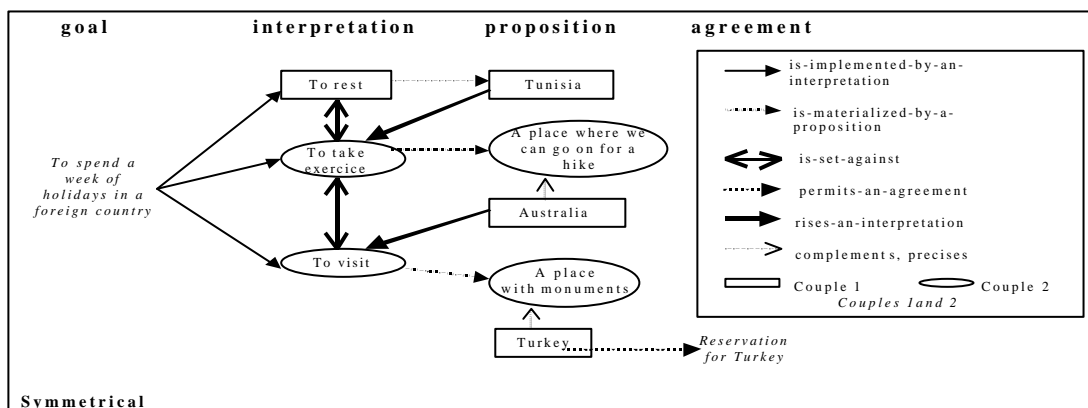
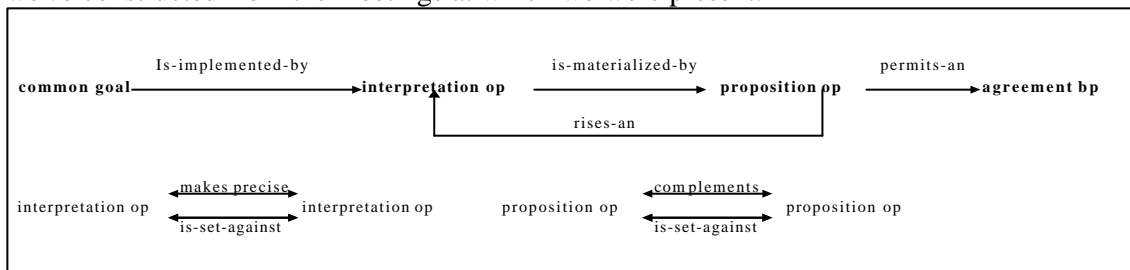


Figure 2: Example of static representation of a symmetrical co-design process and of an asymmetrical co-design process

The dynamic model shows how the analysis categories are connected over time and thus follow on from each other. The decision-making process begins with the definition of a common goal, followed by a party's interpretation and its proposition, a proposition that leads to another party's interpretation. In order to illustrate this model, we shall give the same examples as before, with a dynamic representation (see figure 3).

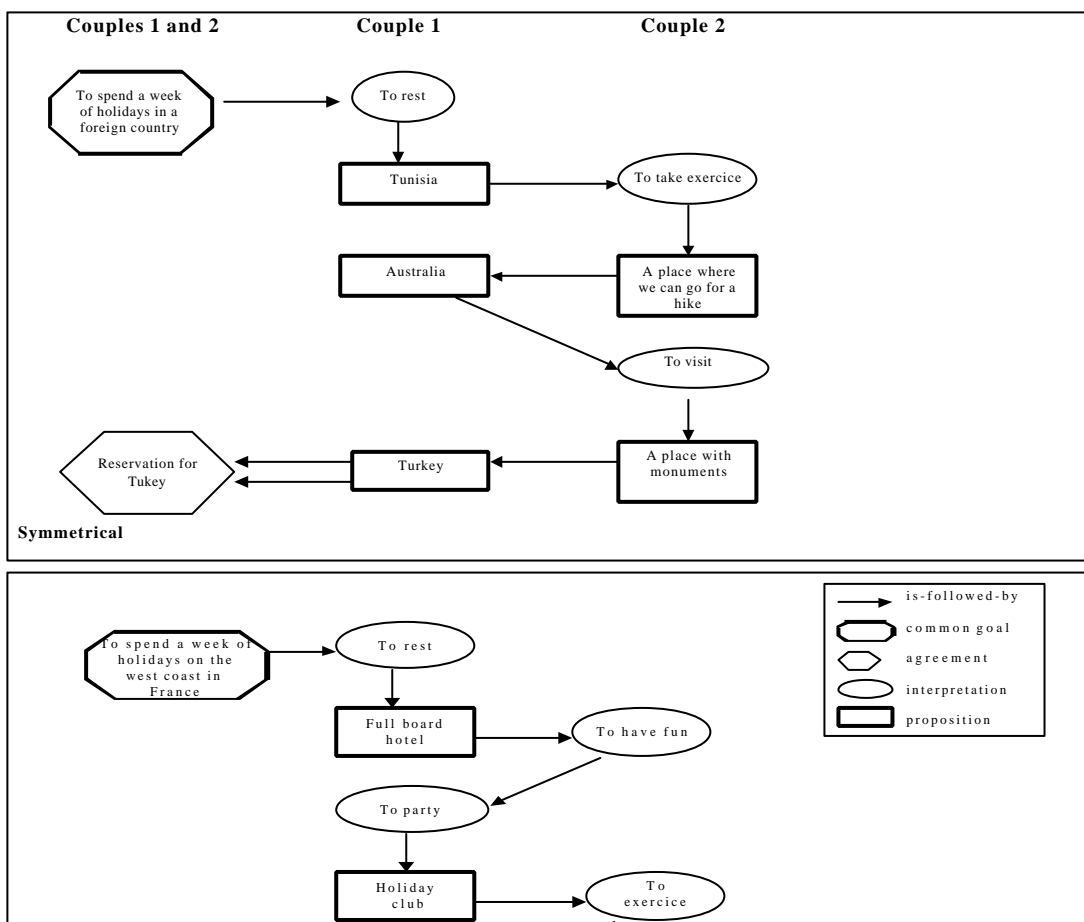


Figure 3: Example of a dynamic representation of an asymmetrical co-design process and a symmetrical co-design process

A decision making process can be composed of alternate sequences of "symmetrical co-design" and "asymmetrical co-design". The interpretations and propositions that confront one another in the models above represent confrontations of all types of points of view.

Application of the models to an example

We shall illustrate these models by means of an example of a decision-making process during collective work meetings whose goal was set by a contract, to wit: the elaboration of a procedure of needs analysis for producing and archiving documents. First we shall give an instance of the dynamic model (see figure 4) in order to allow for a good understanding of the process, then the static model (see figure 5) which will allow for a better understanding of the structure of the process. For the dynamic model, we will specify the order in which to read the schema with numbers on the arrows. For the static one, we will specify above each element the parties stating those elements of discussion.

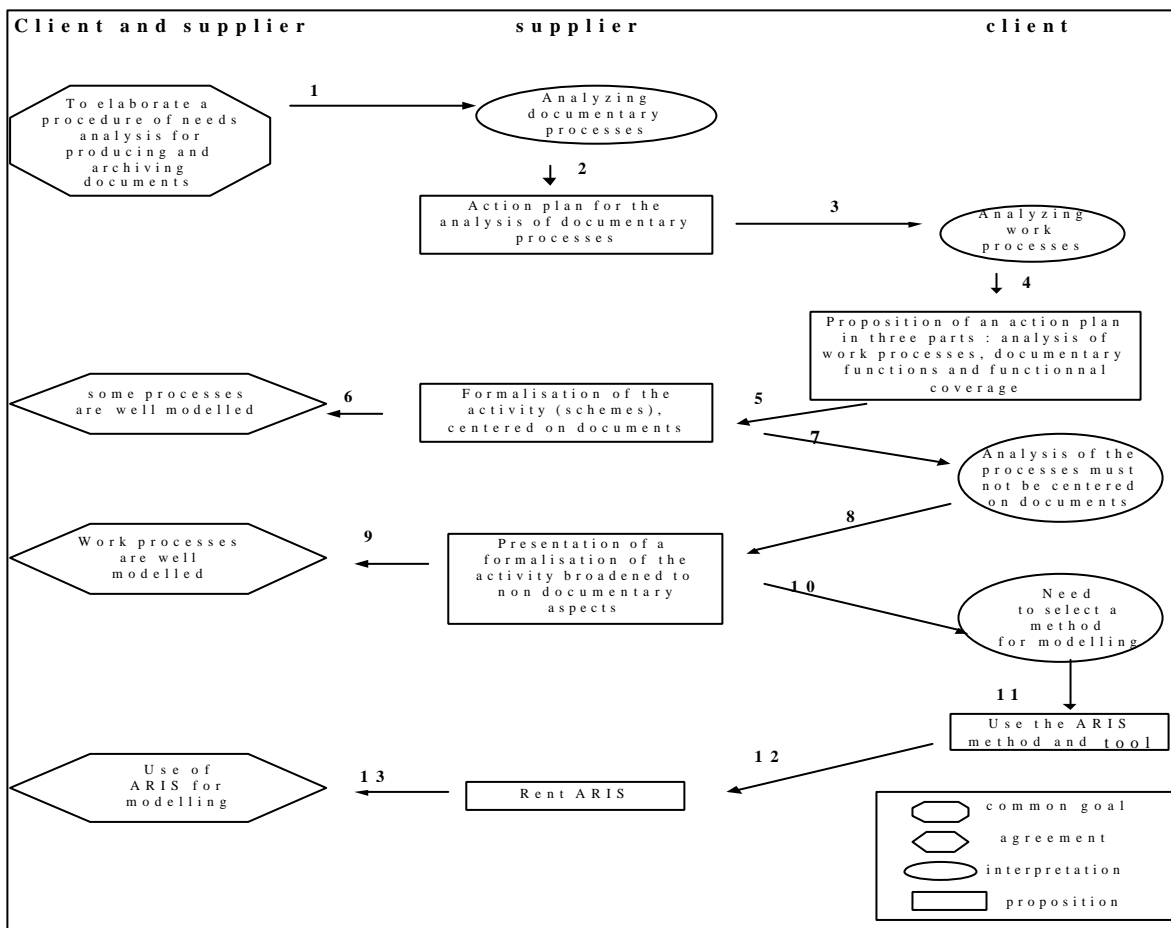


Figure 4: Example of a dynamic representation of a symmetric co-design process

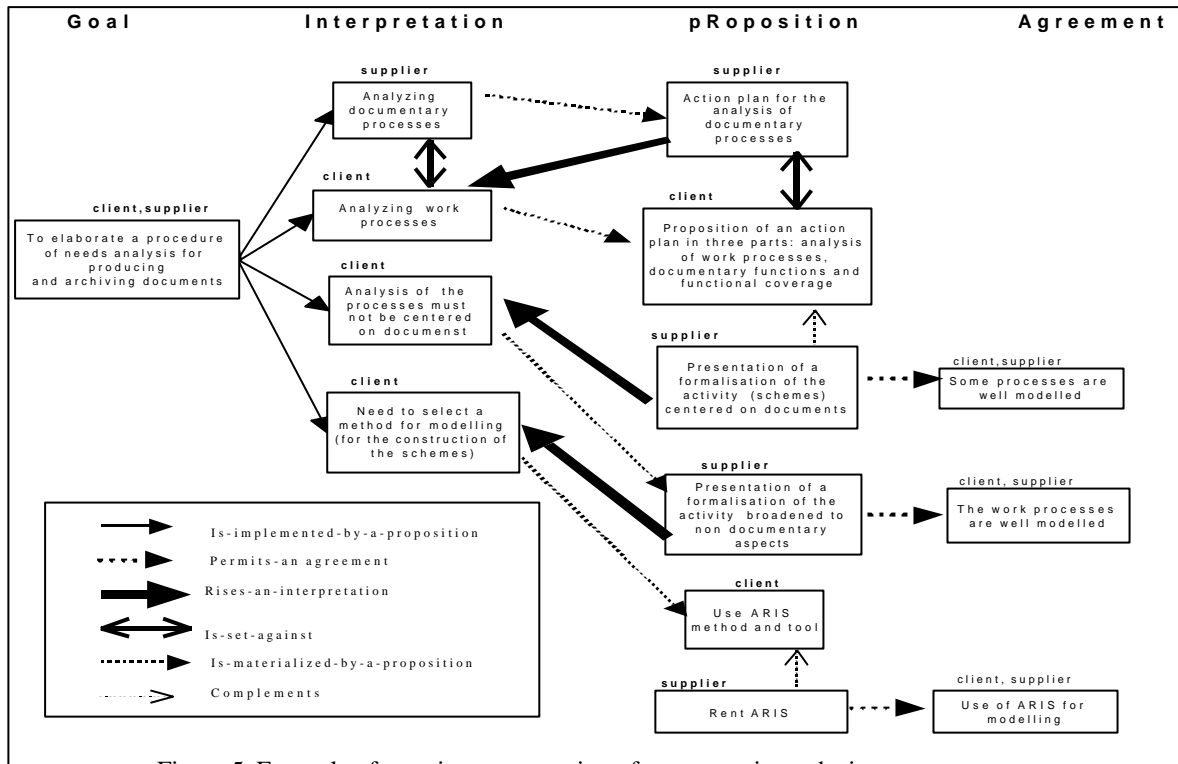


Figure 5: Example of a static representation of a symmetric co-design process

5. CONCLUSION

After having studied Design Rationale, we have concluded that the classic methods of Design Rationale are not suitable in every situation. When the complexity of the problem is low and when the knowledge level about the solution to be designed is high, the classic techniques of Design Rationale, and more precisely QOC (which basic structure that has to be learned is simple) are appropriate. However, for complex situations where "depth-first" research⁷ is made and where it is necessary to account for the dynamism of the process and for the roles of the actors implicated in this process, Design Rationale's classic methods are no longer sufficient.

As we were unable to use the QOC method for modeling design processes in the project meetings at France Telecom, we sought to extend the field of Design Rationale to these complex design situations. To that end, we developed the ABRICo formalism which we used successfully in this project of experimentation of a Document Management System. This formalism represents the evolution of a solution during the meetings, and takes into account the roles of the actors at these meetings.

There is still a lot of work to do for the ecological validity (in real world) of Design Rationale and particularly ABRICo. Criteria for the validity may be the facility for the designers to use the formalism, the adequacy between the formalism's categories and the arguments exchanged. Then, our objective is now to experiment, to enrich and develop ABRICo. To that end, we recently joined a project team at France Telecom whose goal is to overhaul the Information System. Having seen the organization of this project, we already may point out that the representation of a

⁷ That means, as we said before, when designers explore the details of a solution instead of examining several solutions' sketches among which they have to choose.

"client-supplier" co-design can be refined. In fact, we have three groups of actors: first the owner who is a sort of client and who sets out Goals. Next, the contractors who identify functions to be implemented in order to achieve these Goals. Hence their contributions come under the heading of interpretations. Finally, the subcontractor who thinks about ways to implement the functions identified by the contractors. His contributions are therefore propositions.

From this assessment, we can envision a further functionality of ABRICo, which will be added to the rationalization of collective design processes, to wit: the evaluation of contributions by the project's several groups of actors. That is to say: does the owner really set out goals, the contractor interpretations, and the subcontractor propositions?

Thus, taking roles into account leads the way to a study of organizational dynamics within project groups; a factor that management sciences brought to the fore a long time ago and that seems to be pivotal in the construction of collective memory.

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Résumé

Les expérimentations des formalismes classiques de Design Rationale sont concluantes dans de nombreuses situations de conception. Toutefois, nous avons rencontré une situation dans laquelle il était impossible d'utiliser QOC pour représenter les argumentations conduisant aux décisions. Cet échec nous a conduit à élaborer une typologie pour les situations de conception collective, et plus précisément à identifier des situations que nous avons appelées "complexes". Dans ces situations, la modélisation doit représenter l'évolution dans le temps d'une unique solution et les rôles joués par les acteurs pendant le processus collectif de résolution de problème. Afin de mémoriser ces processus de conception collective complexes, nous proposons le formalisme ABRICo que nous avons testé avec succès lors de la mise en place d'une solution de Gestion Electronique de Documents.