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TOWARD A PROJECT MEMORY FOR INNOVATIVE PRODUCT DESIGN, A DECISION-MAKING PROCESS MODEL.

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Abstract

This paper introduces project memories as Knowledge Management systems to support innovative products design projects. An integrated decision-making process model is detailed. This UML model is decomposed in four views, decision organization, decision process, decision result and decision structure. A Project memory based on this model is proposed. Functionalities of this memory are exposed. This word is validated on case studies from automotive industry.

Keywords: Decision-making, Project Memory, Knowledge Management

1 Introduction and objectives

Knowledge management is a key to ensure performance in companies. Our approach is developed within the framework of knowledge management systems for innovative product design projects. An innovative product can be defined as a new product that will become an innovation while bought by customers. As an illustration extracted from automotive industry, the fuel cell-powered cars are such innovative products.

Those projects are specific organizations that use various knowledge resources. Project stakeholders use tacit knowledge (or know-how), which is not specific to innovation and is already hold in the company. Such knowledge is mostly relevant to routine design and is supported by dedicated KM systems shared across the company, like corporate memories or KBE (knowledge based Engineering) systems. Thus, in addition to product development, such projects lead to knowledge creation mainly relative to the new technologies or concepts developed by the project. We observe that this knowledge is unsanctioned and not stabilized due to dynamical aspects [1] of innovation.

If there could be many organizational KM Systems for innovative and creative design, like expert networks, there are few KM tools to support these activities especially for project processes. These systems must handle the specificities of innovative design projects characterized by evolving environments, specific contexts and dynamic knowledge and intensive decision-making tasks. Consequently existing methods and tools for knowledge capitalization concerning product development are inaccurate for innovative products.

The purpose of this paper is to introduce a decision-based project memory as a KM system that satisfies projects stakeholders' needs. A decision-making process model is detailed, as the core of this project memory understand, to describe, and to model decision-making flows of this kind of projects. Our research work is validated on a case study realized in PSA PEUGEOT CITROËN Automotive Research and Innovation Department.

Section 2 draws out the objectives and the framework of our work. Section 3 describes a decision-making model which implementation in a project memory is discussed and validated in section 4. We close in section 5 by discussing concerning our results and the perspective in the definition of reuse mechanisms of the project memory.

2 Framework and objectives

2.1 Decision-making, innovation and knowledge

Our research area is the design of innovative products in project organization. These products have to satisfy two main requirements: the technical and cost requirements and customer requirements. Hence products have to be considered as innovations bringing a competitive advantage for the company. Consequently the performance of an innovative product can be seen from two points of view: its technical performance determined by design activities together with the definition of its requirements ("consumer valuation"). This performance is the result of a wide decision-making process that takes into account the customer representation and its evolving environment, the manufacturing constrains, the evolution of technologies and suppliers' knowledge. Owing to the decision-making process, the product developed will get or not get value according to the consumer. This means that decision-making process determines the success of this kind of projects.

- The decision-making activities may use knowledge as a resource to build hypothesis, alternatives, preference, decision criteria... This knowledge is both explicit and tacit. It is linked to experience and collaboration between projects' stakeholders.
- The decision-making process may also be a learning process. Project managers are learning and memorizing while taking decision in the project. Hence, by handling unstable and unstructured information, multiple views of design and project issues relative to decision, decision-makers improve their knowledge of the domain [2]. The key factors in terms of knowledge creation are relative to decision-making. Namely, knowledge creation highly depends on orientations taken in the projects.

2.2 Toward a project memory

Decision-making appears as the key factor of design projects of innovative products. Consequently, our approach is to focus on KM systems that aim to support the decision-making processes. KM systems for product development can be considered as decision support systems. Hence, they provide designers with knowledge used in design activities which outputs are information necessary to decision-making. However only few KM systems are intended to support decision-making, only Project Memories integrate explicit representation of decisions and knowledge linked to decision-making.

A Project Memory is defined as an explicit representation of the knowledge acquired and produced during a project. A project memory is materialized by a tool supporting the current project activities and the capitalized knowledge reuse. The main purposes of those memories is to support the project by the reuse of any knowledge capitalized from the same project or other projects. Existing project memories in the literature, seek to capitalize knowledge without perturbing actors. They focus on the reuse mechanisms however, two difficulties arise. Existing methods cannot lead to automated capture of the design rationale and the reuse formalism is not satisfactory [3] [4].

However, our proposal is to use project memories as activity support systems, for an instant use, as apposed to approaches seeking capitalization without perturbing actors. At first it should help actors to understand more clearly their decision spaces and decision-making processes which are unstructured [5], their goals, their objectives. This is done through formalization especially in distributed design teams. In order to produce such project memories we underlined in [10] the need for a model able to represent decision-making complexity in innovative product design projects. Such a model is proposed in the next section.

3 Decision-making process

3.1 Toward an integrated model of decision-making

A number of proposals have been advanced in recent years for the study of decision-making processes in the area of management, artificial intelligence and cognition, biology, engineering design… A detailed study of all the aspects of the researches in this area would be out of the scope of this communication but we underline the two main approaches seeking to decision-making modeling. Prescriptive approaches (like operation research) have been widely used to support decision by prescription, optimization and new decision-making process deployment. Furthermore, descriptive approaches aim at modeling in order to study, understand, represent and re-use existing decision-making processes (initiated by Simon [6]).

Our research is developed within the field of descriptive approaches. By a review of the literature concerning descriptive decision-making models from various research areas [7] we underline various ways in which a decision-making process can be modeled. The focus can either be given to argumentation (this is the case of the design rationale approaches [3][8]) or to the structure of the decision space (GRAI R&D [9]). Alternatively decision is described as a sequence of decision activities [6]. We distinguish two main criteria to characterize models (See Figure 1.). *Model capacity criteria* determines if a model of a specific decision-making can be reused in various situations and *Appropriation by users criteria* determines if the model can be easily understood by projects' stakeholders.

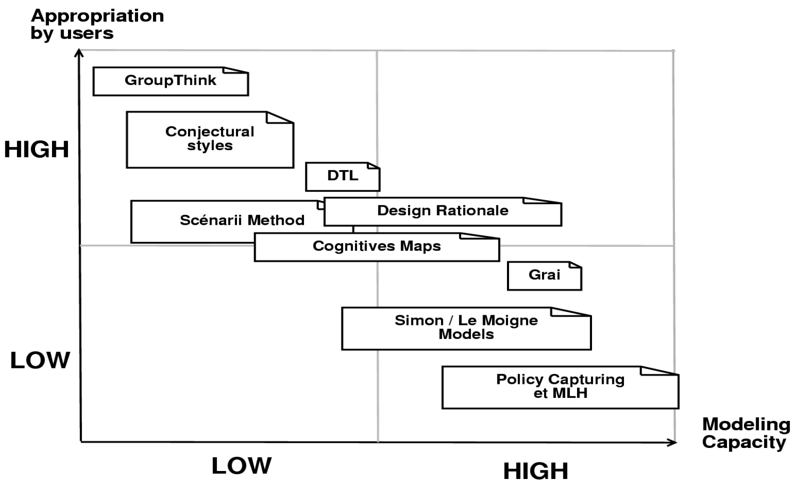

Figure 1. Descriptive models

Decision-making is a highly critical process characterized by its complexity. This complexity is characterized by the interconnections this process has with the various processes across the company together with the fact that decision-making is realized by human beings. This is emphasized by empirical observations made during design projects of innovative automotive systems at PSA PEUGEOT CITROËN [10].

Consequently we insist on the need for an integrated model of decision-making able to link the different components of the decision-making processes. These components are the structure of the decision (alternatives, criteria, … which are usually described by design rationale methodologies [3][8]), the object of the decision (what is decided? It can be a product, a process or an organization), the activities of the decision within the overall decision-making process (problem identification, criteria identification, alternative selection [11]) and the organization of the actors involved in the process.

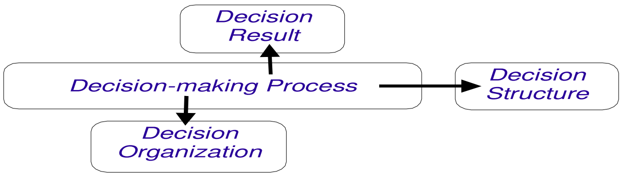

Figure 2. The four views of an integrated model of decision-making

Accordingly we propose a model based on four linked views (see Figure 2.). This model is written in UML (Unified Modeling Language) object oriented language. The *Decision Organization view* leads to the identification and characterization of decision processors (actors or group of actors). The *Process view* characterizes activities of the decision-making process and links between processes. The *Decision Structure view* deals with the structure of the decision and is composed of alternatives, criteria, evaluation, constraints, hypothesis, and links to other decisions and external elements like project objectives and context. The *Result view* is the description of the object concerned by the decision (products' definition, processes' definition or organizations' definition). It can be the choice of technology, requirements, specifications, functionalities, parameters... The model includes the links between the four views; consequently a decision-making process is represented by elements of each view.

Due to layout constraints, only the *process view* UML class diagram is presented. The three remaining views, illustrated by simple sketches, are less detailed.

3.2 Process view

According to [12], "a decision is a process which leads an actor to answer a question". In this paper we consider decision-making as a process of information transformation. This process is collective and can be considered as a release mechanism of operational activities. We have identified through a literature review and empirical studies [10] the main decision-making processes activities. We chose the DTL (Decision Time Line) model as a compromise between the criteria of modeling and appropriation by the users [10]. The activities of the DTL are: Apprehending, Identification, Negotiation, Synthesis and Transmission.

The *Process view* is the core of our model because it sets up the links between all the four views. The process is decomposed in sequences of decision activities linked by information flows. Activities are supported by decision processors (groups of project stakeholders), which are described in the *Organization view*. For instance, negotiating the criteria used to select a supplier is a *negotiation* activity. A decision-making process concerns an object of the real world, which is represented in the *Result* view. For instance, the choice of a car for a prototype. The decision flows, linking decision activities of the process, are intended to describe the components of the decision structure (alternatives, criteria, …) and are described in the *Structure* view. The different UML classes of this model and its links with the other views are best explained by referring to Figure 3.

In order to represent the links existing between the different decision-making processes, the class called *"Constraint"* was added. Those objects are semantic links between activities containing information linking activities from different processes relative to different *Decision Results*. As an illustration, the process activities concerning the selection of a supplier (organizational result) for bench tests is linked to the choice of technology for the bench test components (product result).

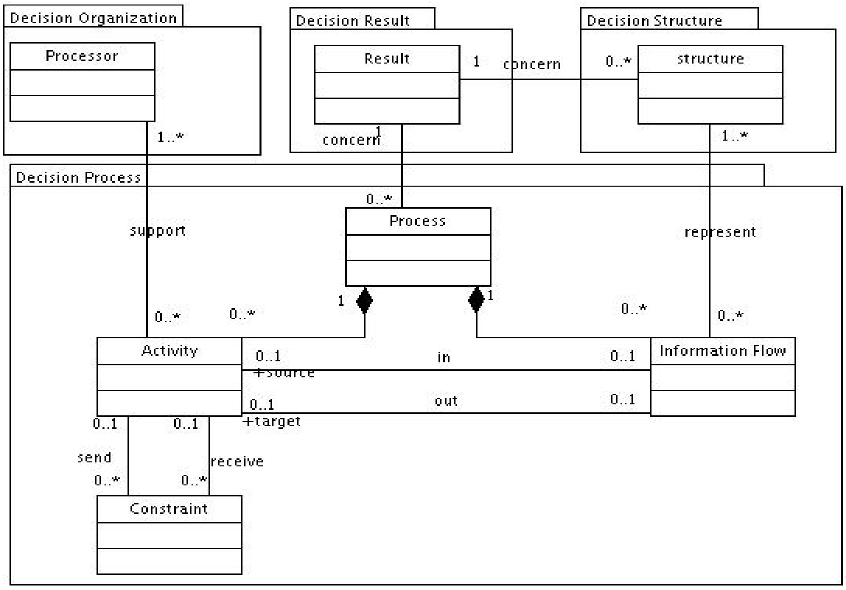

Figure 3: The process view and its links with the other views

3.3 Decision Organization view.

The *Organization view* is represented by different systems in interaction: projects systems, company system, competitors systems, customers systems, shareholders systems, suppliers systems and at least the rest of the humanity.

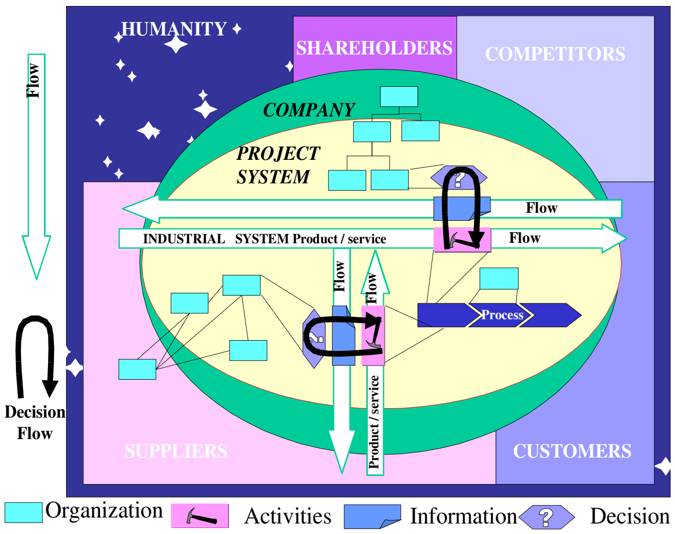

Figure 4. The Organization view

The flows circulating between these systems are then represented Figure 4. Three types of flows are distinguished:

- the activity flows which circulate mainly from the project's actors (it is the operative flow) to the costumers,
- the information flows which mainly circulate in reverse direction,

- the decision flows that allow the control of the activities of each system through the utilization of available information from information flows. The decision-making is realized by an organization of the resources (actors an groups of actors here called *decision processors*).

The purpose of this model is the representation of the organizational structure of these decision processors. The main classes of this model are the *decision processors* containing actors playing roles within the organization. To illustrate, a steering committee is a decision processor composed of 5 actors. One of these actors has the role of project manager.

3.4 Decision result view

The result is defined as a "decidable" object from the real world, the object being handled by the decision-making process. Three types of *decision results* are considered, result within the field of organization, product or design-process. As an illustration, a decision-making process can lead to the choice of a functionality to be implemented in a product, the choice of a supplier or the choice of a specific design method.

We consider three types of result in order to enhance links between decisions. For example, a technology choice can have consequences on the selection of a supplier to realize it. This model can also handle various levels of decision, but we focus our work research on high-level decision like requirements choice or architecture choice.

The other views can be considered as generic models for design activities, this last one must take into account specificities of innovation and the industrial context.

As soon as project memories have to be used by the projects' stakeholders, these tools have to integrate the existing design methods and tools. At PSA PEUGEOT CITROËN, the focus was raised on product modeling. Consequently, we focus our research on decision applied to product. By now, we consider only a product data model including concepts of (i) system / (ii) function / (iii) part / (iv) requirement. A *decision result* can be one of these concepts or a composition of these concepts. For instance, as a *decision result*, actors can consider a motor torque level specification. Nevertheless a specification document, including several specifications can also be considered as a *decision result*.

In addition to theses concepts, we are currently working on the specificities of the innovative products, like requirement analysis decisions due to semiologic, sociologic and cultural constraints.

3.5 Decision structure.

This part of the model describes the *decision structure;* it is an information-based representation of the decision space concerning the result of the decision-making. We propose to illustrate the main classes of this model by a simplified view presented Figure 5.

Solution space is unknown and infinite (for example, group of functions that can be performed by a new steering system). *Constraints* are restraining the solution space. *Alternative space* is the part of the solution space explored and evaluated by the project. *Solutions* are chosen after an *evaluation* under a set of *criteria*. This is done in order to satisfy *objectives* of the project in a specific *context.*

Two important concepts are linked to this model, the concept of *context* and the concept of *objective*. *Context* is a three levels issue. (i) The *collaborative context* is necessary to understand the interactions between actors while deciding. (ii) The *linguistic context* is necessary to understand information in texts and documents. (iii) The *overall context* helps to understand the links between the project and its environment.

The concept of objective helps to explain the motivation of the actors while deciding. These two issues are not yet formally integrated in the UML model.

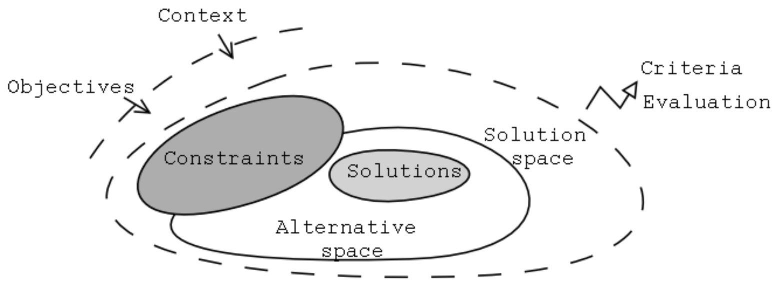

Figure 5. Decision Structure.

4 Meydiam

4.1 Project Memory specification

Meydiam (MEmorY of DecIsion for Analysis and Management) is a project memory defined for a case study at PSA PEUGEOT CITROËN. This case is a distributed design project of innovative product in collaboration with suppliers design teams (co-design). The core of this project memory is the integrated decision-making model described above.

The users of the memory are identified within the organization. To put it more precisely there are two kinds of users: (i) users who need information from the memory apart from the quality support, they are mainly managers in charge of several projects; (ii) projects' stakeholders involved in decision-making in projects who are mainly project and sub-project managers.

Then the main functionalities of the project memory are identified by a functional analysis:

- To inform users about the decision-making processes (past and present), the decisions taken and their associated decision space, the actors involved in the decision.
- To analyze the links between processes, the various roles and competencies of the actors involved in the decision, the performance of the processes and the generic types of decision.
- To deliver minutes of the decision taken, documentations of the project, return of experience.
- To use and reuse decision in another context, in another project, to identify patterns of decision by knowledge extraction from the decision database, to identify good decision practices.

4.2 Software prototype.

To support those functionalities, a software prototype was designed. It is based on *Apache* web server with *Php* module and a *PostgreSQL* object-relational database in order to implement UML class diagram. We still not have implemented all the functionalities, focusing only on decision-making traceability.

Take, as an example, the choice of the car model to validate an innovative steering system.

The result of this process is the selected car model. By now, this process is launched and contains two activities (apprehending the issues and identification of the solution space). As illustrated by figure 6, the *process view* represents these activities, their associated decision processors, and the information flows along with the constraint from another process. As described by Figure 7, the output information of the last activity can be shown graphically. The filled octagon represents the *result* and the linked shapes represent the components of *the decision structure*.

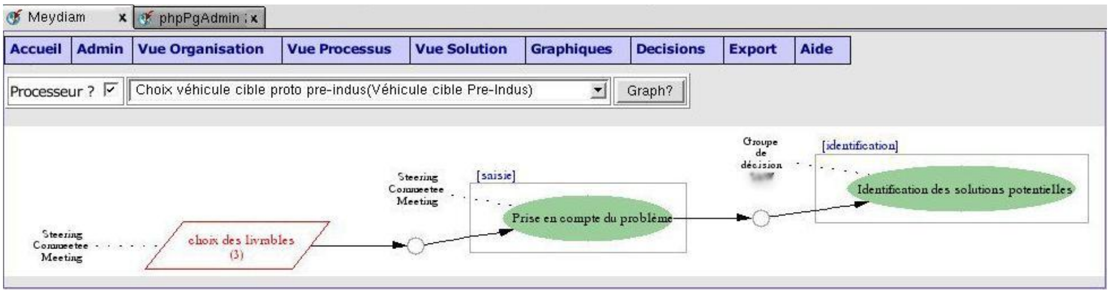

Figure 6. Meydiam Decision Process view

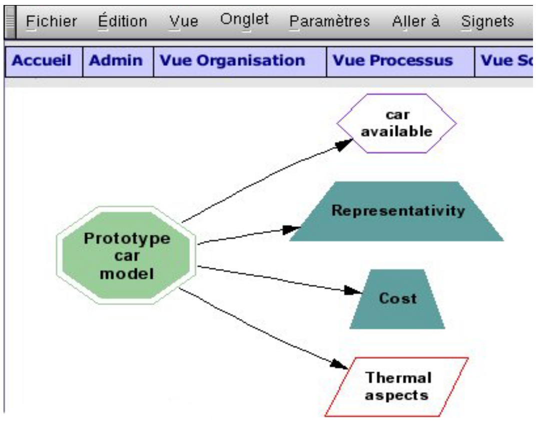

Figure 7. Meydiam Result View

4.3 Project memory: use and validation

The project memory validation have to be done following several points of view such as time and cost reduction, problem solving support, communication enhancement between project members, conflicts resolution, innovation process support. *Meydiam* is not fully realized, especially concerning the reuse mechanism. Consequently, final results and validation will be exposed in future papers. Though, we can already draw out conclusions.

The available information concerns the project memory used as a tool to represent the decision-making process during the project and not yet as a tool for reuse and analysis. Experimentations were carried in order to formalize decision taken by the project and sub-project managers. To begin with, the satisfactory results concern the integrated aspects of the PM. Contrary to project memories that are based only on design rationale, the different views of the models allow the representation of complex transactions. This helps actors to enhance their interaction and communication by sharing knowledge through the four views of the decision-making. The project memory is not intended to represent exactly how the decisions are taken but it gives a shared structured language to support communication and conflicts solving concerning decision.

As a support to innovation processes, the benefit can only be shown in the long run.

Nevertheless, at that stage, we only observe that the project memory helps to represent the decision space of the project. The project managers can improve their strategies by identifying the paths that have been explored and which issues are still opened.

Concerning the documentation issues, especially the justification documents, the project memory can help identifying undocumented critical decision-making processes and produce most of the required information for documentation. Project memory can also be used to prepare decision meeting and meeting minutes writings. To this end we propose to use structured forms integrated in documents (agenda and meeting minutes) to interact with the memory.

The main identified limit concerns the level of decision to handle. As an illustration, during a five attendees steering committee meeting concerning a design project of twenty actors:

- more than 25 high-level decision-making processes (as technology choice) are considered,
- more than one hundred medium level decision-making processes (as technical issues, requirement analysis...) are considered.

It is not realistic to formalize all the decisions. Consequently it is necessary to identify which decision has to be modeled in the project memory. Hence, researches have to be done in order to provide users with methods in order to identify which decision is crucial.

5 Conclusion

Our approach is developed within the framework of knowledge management systems for innovative product design projects. In this paper we described links between knowledge, innovation and decision. Project Memories were proposed as KM tools to support decision-making in project processes. Then we presented a project memory and a software prototype based on a decision-making process model. The four views of the model (process, decision organization, decision structure and decision result) were described. Their purpose is to handle complexity and multiple aspects of decision-making processes. Then the results were discussed. We outlined the need for in-depth studies in order to help users to identify critical decisions.

The main perspectives for further researches concern issues encountered during the capture process of the decision-making and the reuse of the project memory.

- We have to find efficient ways in order to integrate use of the project memory in actors' day-to-day activities.
- Tools that could help to acquire automatically from documents the rationale of the project are required and have to be studied in this context.
- We expose the idea of "decision patterns" extracted from the project memories in order to acquire knowledge and to evaluate the performance of the overall decision-making. The objective is then, to share the best practices in terms of decision-making.

In the long run, the information available in project memories will lead to in-depth analysis of decision-making processes. Then, this descriptive approach will provide enough knowledge to start project decision-making processes optimization. Although this project memory is defined in the context of innovative product design projects in automotive industry, this type of memory should be tested in other domains by adapting the *Result view* of the decision-making model.

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