An application of MACRAME to support communication and decisions in a multi-unit project

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Maria Franca Norese
DISPEA - Politecnico di Torino
Corso Duca degli Abruzzi 24 – 10129 Torino, Italy
mariafranca.norese@polito.it
tel 00390110907279, fax 00390110907299

Abstract — Researchers from the Politecnico di Torino working in different fields and a start-up company from the internal incubator decided to join together in a collective project to produce an innovative light aircraft that would utilize hydrogen as fuel. Several decisions have had to be made, above all in relation to the hydrogen fuel cells that have to be used (dimensions, number, supplier,..) and to the electric propulsion engine that has to be combined with the cells as there was no engine on the market with the adequate characteristics. The consequences of these decisions (and of others, in relation to the electronic devices and the automatic control systems), in terms of times, costs and risks, have had to be analysed in the project context, where units with different expertise and language were involved.

The paper proposes a methodological approach to identify and face uncertainties and complexities pertaining to this multi-unit project through a shared vision of the problems and a structured and evolving problem formulation that has been developed to support communication, coordination and decision-making. It explains how some tools have been integrated in this application and used to elaborate and represent alternative decisions, to collectively evaluate and choose and to create a communication space for the project.

Key words: decision aiding, collective problem formulation, problem setting and structuring, communication tools, cognitive mapping

1. Introduction to the problem situation

In the last few years, some technological innovations have led to the ideal condition for applied research projects on electric propulsion combined with hydrogen fuel cells. In the aircraft design and development context, some research projects have had the aim of demonstrating the feasibility of a piloted flight, with the electric propulsion and energy being derived only from hydrogen fuel cells. Some of these projects have been financed, for example, by the European Community, and have involved several research units and companies from different countries, with consequent coordination difficulties that can induce a waste of time. Some others are commercial projects, with all the required resources, but also the constraints, that are present when an innovative aircraft has to be put on the market.

"Sky-Spark", a small internal Politecnico di Torino project, was activated to involve only a few participants, with the required competencies, who are interested in the challenging possibility of producing an innovative and "greener" light aircraft that utilizes hydrogen as fuel.

The Sky-Spark project team includes four Departments at the Politecnico di Torino and DigiSky, a start-up company from the internal incubator, while all the other partners (technological or financial sponsors) are located in and around Turin, as are the main component suppliers. These conditions lead to agility in coordination and in project management and they could determine a competitive advantage for the Sky-Spark project, which could produce the first hydrogen-supplied aircraft in the world to fly with a pilot. This dream, which originated from the passion and competence of a team of engineers, could lead to new perspectives in the aeronautic field, as a result of the conjugation of three competitive factors: innovative technology, ecological aspects and commercial attraction.

However, some technological, managerial and organizational criticalities have arisen. The president and the technical director of DigiSky are expert managers who work in other organizations; DigiSky therefore knows how to face a situation with an evident managerial attitude, while the university researchers naturally tend to consider the project as an element of their research environment. The two logics are totally different and several misunderstandings could arise. They can induce complexity and uncertainty that are crucial as far as product and process innovation and development contexts are concerned.

These contexts should be analysed in depth to reduce complexity and uncertainty and to manage innovative and unstructured situations. In relation to these criticalities, the Sky-Spark project team asked the Department of Production systems and economics at the Politecnico di Torino to be involved in order to support the conceptual phase of the design process with "management tools" and to facilitate the definition of the project development activities, above all in terms of required time and related costs.

Classical project management, functional analysis and multicriteria analysis tools are currently proposed in the Management Engineering courses at the Politecnico di Torino, but the students only use these tools in the laboratory, in relation to totally or partially structured problem situations. For this reason, the Department decided to participate in the project, as it offered some students an opportunity to test their abilities in a real, but not very complex situation.

A thesis project was proposed to some students, to support the conceptual phase of the Sky-Spark project and to integrate different tools in a methodology, MACRAME, which facilitates problem formulation and model structuring when the different visions of the involved actors are the main elements of an analysis.

Three students developed the thesis project, and adopted an action research approach in which a systemic perspective was used to understand the situation and to propose a multidimensional reading of the organizational, technical and financial characteristics of the project. MACRAME was used to organize actions at different analysis levels and to control the global consistency of the different models that were proposed to the project team.

In the next section, the paper describes the main characteristics of the Sky-Spark project. The third section analyses MACRAME, a methodology that can be used to acquire a systemic perspective of the main characteristics of a complex project, and to orient communication and action. The MACRAME application is described in the last section, with a synthetic description of how the tools that were used for this application were integrated in a communication space to underline problems, structure decision models, elaborate possible alternative decisions and propose them for collective evaluations and decisions.

2. The Sky-Spark project

The Sky-Spark project falls into a particular temporal context. In 2007, the International Aeronautic Federation assigned the World Air Games (WAG) to the city of Turin. These games are like the Olympic games, but in the field of aviation activities, and they were scheduled for June 2009. The WAG event is an occasion to attract the media from all over world. For this reason, the focal target of the project, which started in 2007, was to participate and set a speed record for the light aircraft class. The partners believed the WAG event would offer sufficient visibility to the Sky-Spark project to attract sponsors.

Sky-Spark is only a small research project. It could be considered almost as a “hobby-project” for some people who are passionate about flying but, at the same time, are fully competent in the field. The size of the project and the level of competence of the participants can induce agility in coordination and in project management (more than in a European research project or in a commercial context), but also heavy cost constraints. This means that each possible supplier had to be carefully identified, and the WAG opportunity was considered important from this point of view. However, attaining a speed record for the light aircraft class also implied several requirements.

From a technological point of view, the most critical uncertainties concerning the Sky-Spark design were: which aircraft components had to be selected to have a sufficiently light weight to enable take off and to improve aircraft speed and how to assure the flight autonomy that was required for the speed record, in safe conditions. Higher autonomy was required; more hydrogen was needed, with procurement problems, costs and risks connected to the hydrogen storage. The consequent weight limits meant that it was not possible to carry back up components. Therefore, all the aircraft components had to guarantee very high reliability.

There was also evident conflictuality in the project targets:

- the costs had to be minimized, because this was a small project that did not have the financial resources of a European research project or of a large company; however, the high quality of each aircraft component was essential to guarantee reliability and safety;
- the component costs could have been limited but only if all the commercial channels had been activated and controlled or if at least some components were produced locally, but these approaches would have led to delays, which would have been critical due to the time constraints created by the date of the WAG event.

Figure 1 describes the complex relationships between targets and constraints that the Sky-Spark project imposed. In this context, the consequences of "making or buying" decisions, in relation to some aircraft components, had to be analysed in terms of required time and associated costs and risks. This analysis required good knowledge of the project development, from all points of view: the system design of the aircraft, the choice, acquisition and testing of the hydrogen\fuel cells that had to be used and the electric propulsion engine that had to be combined with the cells, the development and testing of the electronic devices and the automatic control systems.

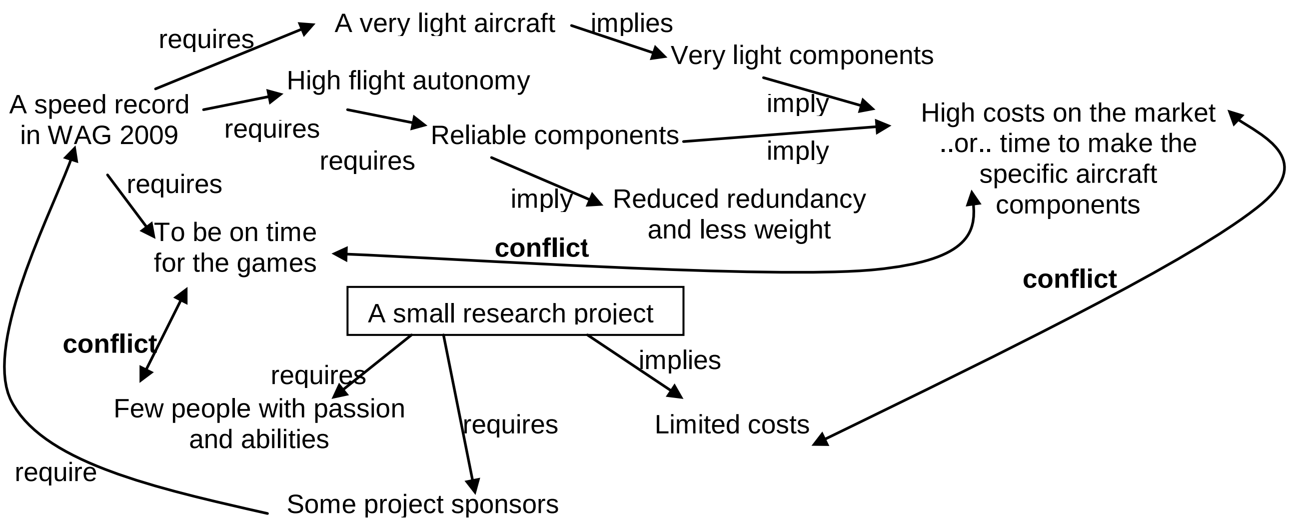

Figure 1 – Targets and constraints and their relationships

These criticalities could be faced, from a technological point of view, with the support of some analytical tools. Gantt and Pert (see, for instance, Ahuja and Thiruvengadam, 2004) were used to analyse the sequences of activities and to find the critical path that had to be monitored and “reinforced” with all the available resources, and multicriteria models and methods (see, for instance, the analyses of their specific characteristics in Vincke, 1992; Belton and Stewart , 2002; Figueira et al, 2005) were proposed to compare the alternative decisions in relation to all the different points of view.

The situation, however, could be more critical from an organizational point of view. The limited dimension of a project could result from a decision, in order to ensure easy coordination, but coordination and communication difficulties could also be present when the project units work in the same university. Coordination and communication problems existed in this project. Each project unit worked autonomously in a university department and a global vision of the interconnected action and decision areas (Friend, 1989) was particularly difficult.

The initial request for management tools to support the project should be interpreted as a request for a rational analysis to control the Sky-Spark project mechanism. The actual situation was different and required a more global vision. A young and brilliant researcher can work enthusiastically (and without financial resources) on an interesting project, but when a real technological innovation has to be developed his/her department could require institutional recognition of the possible results. This involves a long administrative procedure that, in this case, could slow down the project. A researcher who has abilities and an important role in the project, but who also has a great number of duties, could consider communication as a critical waste of time. This lack of communication could mean that no one would know the progress of his activities. In this situation, coordination is very difficult or even impossible.

In the design processes, where multiple communities with highly specialized technologies and different knowledge domains are involved, *defining a common language for the actors* is vital to create an exchange of knowledge concerning common problems (Coates et al, 2004). All the aspects that are relevant in the design should be managed to become coherent in relationship to each other; such technical, managerial and organizational aspects can be individually modelled and related to each other through a common integrated framework (Brown and Duguid, 2001; Carlile, 2004).

For this reason, our intervention was organised as a hybrid-approach, i.e. as a proposal of a new and integrated use of tools, which were sometimes very simple and which adopted a visual and logical language, but were sometimes more analytical and structured and oriented towards modelling the whole problem situation or towards elaborating optimal solutions for specific problems. This approach integrates the tools in explicit communication contexts to reduce uncertainty, facilitate knowledge access and transfer and control the coherence of all the used knowledge elements. These tools have to use the same language as the analysed system, therefore they are not perceived as external to the organization and can produce validated knowledge and information for the decisions that have to be made (Montagna and Norese, 2008).

This kind of intervention has to be oriented and controlled by a methodology that adopts a systemic perspective. It has to support the intervention when it assumes the characteristics of an action research, with the aim of improving communication, practices and strategies in a progressive and shared way that has to be totally documented to allow the students who were involved in the project, but also all the project units, to critically analyse the results, to identify weaknesses and to discuss uncertainties that become evident.

3. The methodology

Several methodologies adopt a systemic approach. Flood and Jackson (1991) have proposed a structured analysis of their characteristics. These methodologies can be used to structure complex problems, and the Soft System Methodology (Chekland, 1981; Chekland and Scholes, 1990) is perhaps the most famous. The Strategic Choice Approach (Friend, 1989; Friend and Hickling, 2005) and its DSS STRAD were above all developed to reduce the uncertainties that make decisions difficult when there are various interconnected decision areas. An application of this methodology has been developed in relation to a specific space-mission case study (Norese et al, 2008), to support the design of complex systems that have to be decomposed and given to specialists from different disciplines. A cognitive mapping approach (see, for instance, Eden, 1988; 2004 and Johnson and Lipp, 2007) is useful to understand the situation and to represent it to the involved actors.

The methodology that was used in relation to the coordination of the Sky-Spark project, MACRAME, includes a cognitive map, which is used to support a shared vision and communication, and is oriented towards structuring the problem, like all the methodologies proposed in (Rosenhead, 1989). The multidimensional reading of each analyzed situation is a specific characteristic of the adopted methodology. MACRAME, a Multiple-ACtor-RepresentAtion-ModElling tool, was specifically developed (Norese, 1995; Buffa et al, 1996) to support modelling-validation activities in situations with multiple actors and difficult communication, where all the knowledge elements that are required for the decisions have to be acquired from the involved actors.

In the Sky-Spark project, the actors are the project units and MACRAME is used to activate some analytical and visual tools to acquire their ideas about the project and about their activities in the project, and then to structure these concepts in formal representations and decision models. The knowledge elements can be confused, contradictory or equivocal. MACRAME is used to activate sequential steps in which the actors' representations are structured, from the analyst's point of view, and then critically analysed and restructured with the decision makers and/or the involved actors, until a global representation of the problem is accepted.

The multiple functions of MACRAME (formulation of the problem, knowledge acquisition, model structuring, validation and documentation, model management) have been used in different ways in situations with criticalities of different nature. When the initial client's demand resulted to be too generic to easily arrive at a clear problem formulation or the problem situation resulted to be very ill structured, several problem formulation and model structuring steps were required. In (Norese, 1996) four schemes, with different topics, contents and structures, were elaborated in relation to four structuring cycles and any substantial change was memorized to allow control activities to be developed, in order to critically use all the produced and documented elements in the new structuring phase and ensure global coherence.

A specific application of the model management function (Norese and Sarboraria, 1998) allowed the analysts to develop a Model Management System (Baldwin et al., 1991) that can change the model structure or modify parameters and information elements, in relation to the new requirements that arise continuously in an advanced engineering education context. In the last few years, the MACRAME cognitive mapping approach (which is activated by the problem formulation function) has become very useful for several inquiring activities to analyse interviews and structure the acquired knowledge elements. This cognitive mapping approach has produced interesting results that have been used to change organizational functions (see Norese and Salassa, 2010). It has also been used to support the conceptual design of a new technological and organizational system, which includes Unmanned Aerial Vehicle platforms and ground stations, where the interviews have been used to identify and analyse the needs of the possible users (Norese and Liguigli, 2009).

The main functions that were activated in relation to the Sky-Spark project were knowledge acquisition and model structuring, validation and documentation, where the term "model" indicates the formal representation of each decision problem and its possible actions. The client's demand ("aid in project coordination") resulted to be sufficiently clear and the multi-actor context resulted to be known. The main criticalities of the application pertained to the difficult communication between the actors and the client's original belief that some analytical tools could "automatically" improve communication and project coordination.

In this case, MACRAME was mainly used to support the analyst's activities in the project (i.e. according to the original purpose of the methodology), but some tests have been oriented towards improving the use of its structured schemes, which synthesize all the knowledge elements, in decision contexts that imply quick (and often wrong) decisions, but accept a critical revision of the previous decisions.

A modular and multilevel schema and a map are activated, for each MACRAME application, in relation to a "problem" topic. The Multilevel Schema breaks the problem down into levels of growing specification and lower analysis complexity and into modules, which propose the knowledge elements pertaining to a specific "component" of the problem and which are essential at a specific level of problem structuring and modelling. The basic MACRAME elements are proposed in each module, and in a modular way, at each level, starting from the General Level, i.e. the global view of the problem situation, and going on to the last level. The elements of each module of the Multilevel Schema are: *problem formulation*, which may be expressed by one or more of its possible structures (*statement of the problem description, actor structure network,* which represents the actor structure related to the level, and *representation networks,* in which nodes represent concepts and proposing sources and arcs denote relationships between concepts), the *dimensions of the problem* and the *dimensions of model structuring (or structuring dimensions).*

The dimensions of the problem refer to the main uncertain or critical elements of the specific problem (or sub-problems) that is analysed in the module. The problem dimensions have to be treated separately and then integrated in a global view. The structuring dimensions act like transition structures from a problem dimension to a problem treatment activity that is explicitly required, from one part of the schema to another and from one level to another, which is activated when a new level of representation structuring becomes possible or necessary.

The Map is another scheme that allows a dynamic view of the analyst's intervention and the results to be obtained, in relation to the knowledge states that the Multilevel Schema produces and organises in modules.

Local formalised results can be obtained at almost all the different levels, but only at the last one can the global representation be formulated in relation to a sufficiently structured and therefore reduced complexity. All the elements in the decision problem model are shown as explicit mutual relationships and are related to sources and proponent sectors or actors. The view is global and its consistency can be tested because each knowledge element has to be read in relation to all the others and each partial contradiction or incomplete treatment has to be faced.

The Multilevel Schema and the Map offer both a global view of the problem structure and the possibility of navigating through the Schema modules in the "structuring phase" and then in the collective "critical reading phase" in order to analyse, discuss and change some basic elements of the problem structure and/or some relationships between these elements. Modifications of the Schema can be frequent in the "structuring phase"; any change is stored in the "Steps" file that is attached to any specific application, and which can be used in the modelling phase or in future model-management actions. Substantial changes require control activities to ensure global coherence and can induce a new "structuring phase".

3. The intervention

The project has involved different departments of the Politecnico di Torino and DigiSky, a start-up company from the Innovative Enterprises Incubator at the Politecnico di Torino, whose technical director is Maurizio Cheli, a test pilot and a member of the 1996 Space Shuttle flight crew, who was responsible for activating the Sky-Spark project.

The most involved department was the Aeronautic and Space Engineering Department (DIASP). This Department has institutionally represented the core of the project at the Politecnico and has organized all the systemic aspects. The Production and Management Engineering Department (DISPEA) has been involved in order to support DIASP and DigiSky in the project coordination and to guarantee the planning of the activities and the management of the project. The other departments, Electrical Engineering (DELET), Automatics and Computer Sciences (DAUIN) and Energy Engineering (DENER), have studied specific technical aspects (for instance the power-line, the propulsion engine and the automatic control systems). Their decisions have only been autonomous in some cases, while, in others, they have had to be made with the coordination group. There are also some external partners and the multiple interactions with the suppliers and the technological and financial sponsors have also had to be considered by the coordination group. Environment Park (EnviPark), which is the regional institution for research on advanced solutions and innovative technologies in the energy and the environment fields, is one of the external partners. EnviPark has played a focal role in the relationships with local public institutions and has also provided technical support in the experimentation.

The DISPEA unit used MACRAME at the start of the intervention (September 2007) to produce a first formulation of the client’s problem, then the project coordination group (DIASP and DigiSky) used the methodology, together with members of the DISPEA unit, to analyse the problem, to decide which procedures of knowledge acquisition had to be activated and to integrate the data processing, visualization, validation and documentation activities with tools that would support communication and decisions.

The MACRAME break down of the “Project coordination problem” into four levels of growing specification and seven modules is represented by the Multilevel Schema (see figure 2).

The initial problem situation, from the project coordinators’ point of view, is described at the General Level. The following levels specify elements of the problem through *statements of problem description.*

Actor structure networks and/or *representation networks* are used when these structures facilitate the *problem formulation.* The actor structure network (ASN), at the General level (figure 3a), represents the initial general vision of the project coordinators. It is different from module 1.2 at level 2 ASN (figure 3b), where DISPEA is involved in the coordination group, with the job of analysing the internal functions, in order to define some new communication protocols concerning project coordination. The responsibilities of the units are known and indicated in the level 2 ASN, but the operational relationships are not present because they still have to be defined. This ASN represents the analyst’s proposal of action that the coordinators have accepted and legitimised.

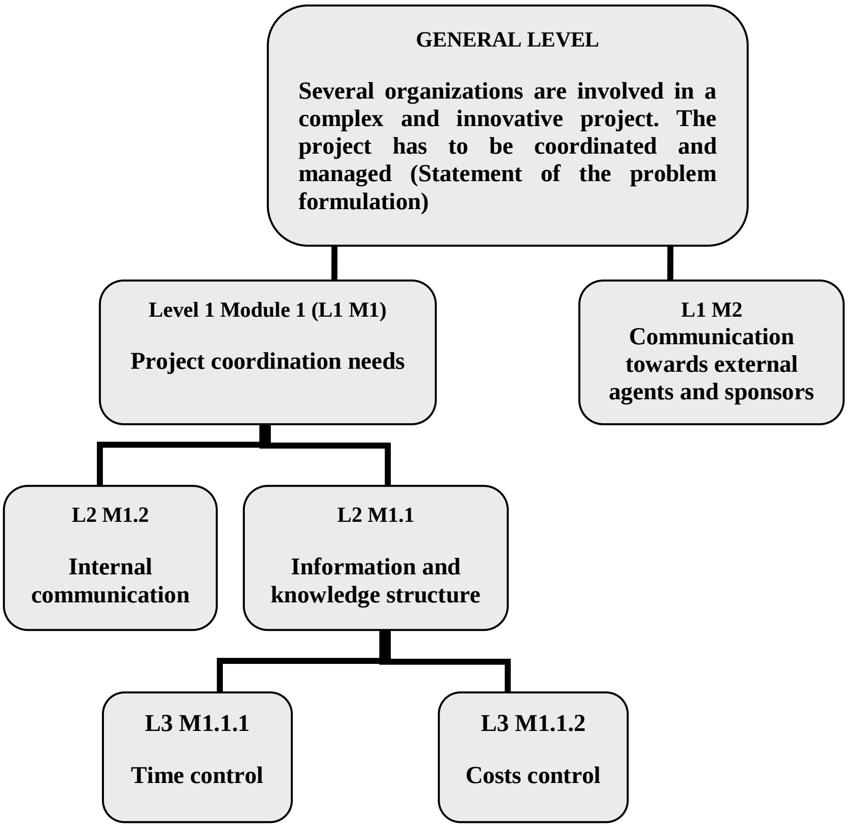

Figure 2 - The Multilevel Schema

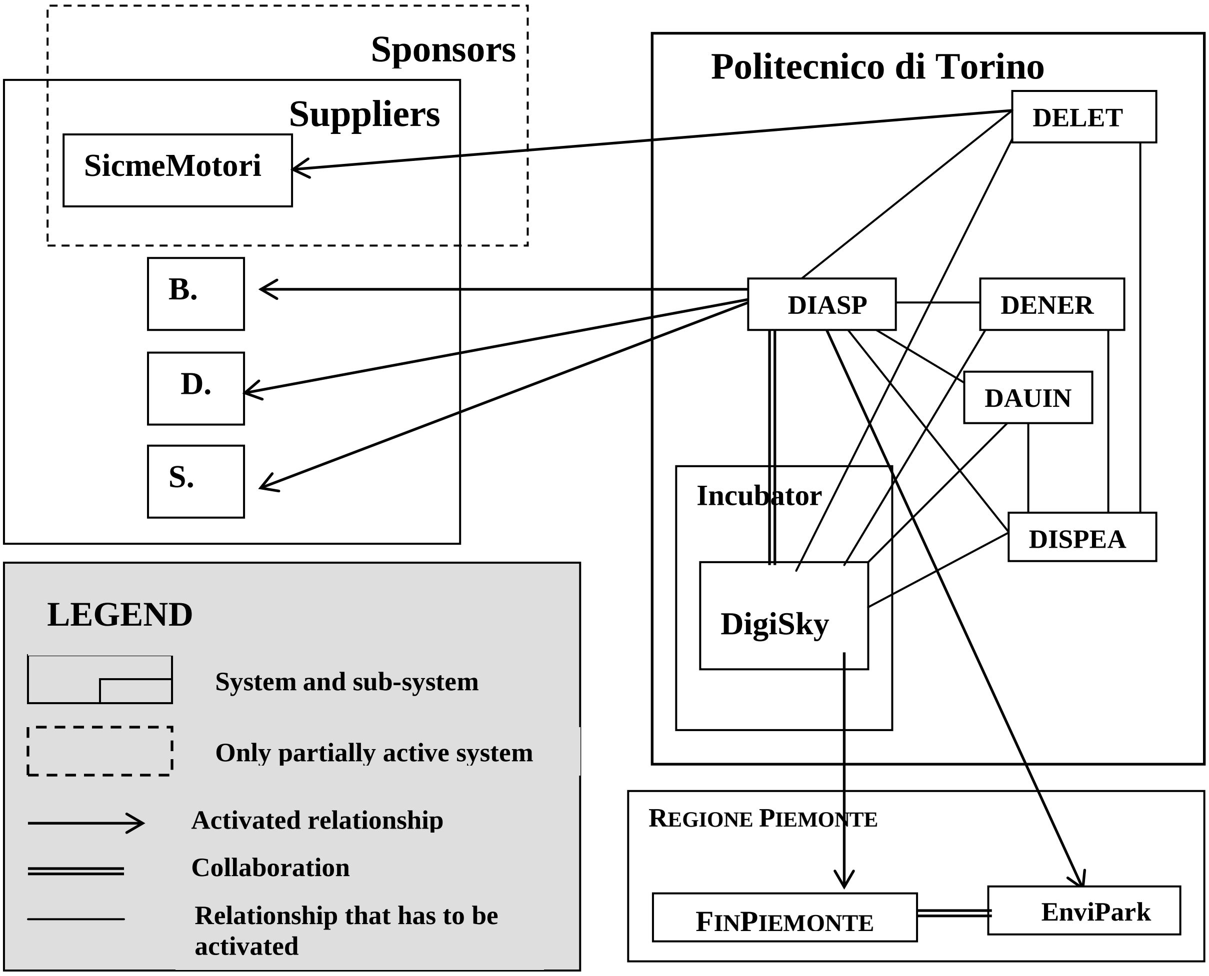

Figura 3a - Actor network structure at the General level

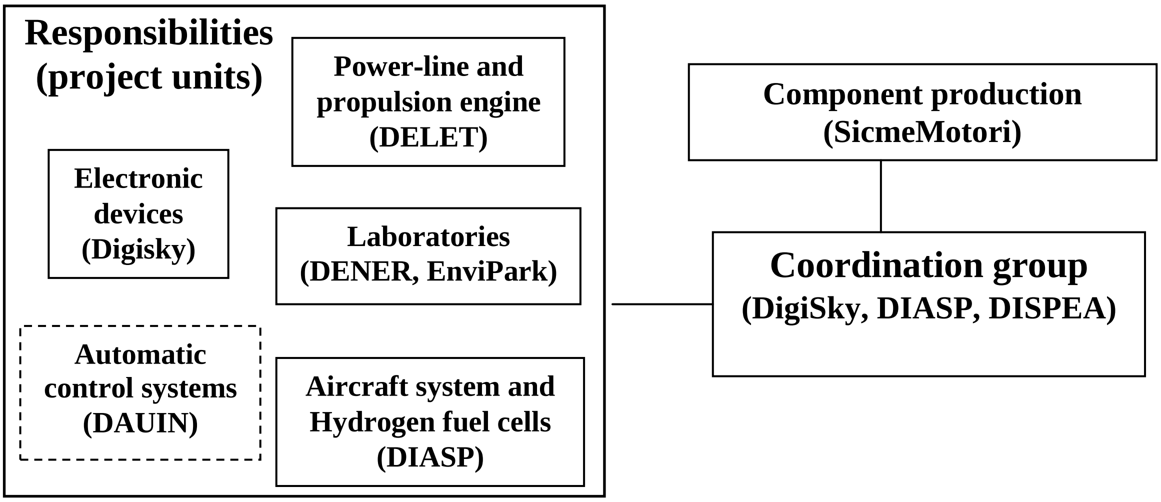

Figura 3b – The actor network structure of module 1.2 at level 2

Some representation networks are used to define the possible problems when the visions of some actors, in relation to a specific topic, are different, and the relationships between the different points of view have to be analysed to understand the situation. Two clusters of concepts, which the actors proposed during the interviews, and possible relationships are shown in figure 4 in relation to two topics: the choice of a communication SW tool for the project teams and the prevision of the date the prototype would be completed. The coordination group analysed the clusters and used these representations to understand some organizational complexities (above all in relation to the DELET role in the project) and to avoid potentially critical decisions.

A complex problem can be broken down into its main sub-problems and these have to be analysed and treated separately and then integrated with the other sub-problems from a global point of view. If the integration presents difficulties or inconsistencies, all the sub-problem analyses (which are documented in the modules) have to be verified to find the causes and to control them.

The transition structure from a problem or sub-problem to a problem treatment activity that is explicitly required is made possible using the *structuring dimensions*. The Map in figure 5 synthesizes the activities and results of the intervention. This map consists of 'elements' and 'connections'; the elements are either intermediate or final states of knowledge (which are synthesized in the MACRAME modules or in the results of the tool applications that the modules activate); the connections are refinement steps which lead from one knowledge state to another. Each step is associated to a specific structuring dimension and, in some cases, to activities that have been classified in Lendaris (1980) as operations, assumptions and □nformation requirements. The activities and results of the action research intervention are described with the aid of this Map.

3.1 Initial formulation of the client's problem

At the General Level, the main problem dimensions are the uncertainties of the coordinators concerning the costs and the required times for each activity, the need to control some technical requirements and the organization of the project team.

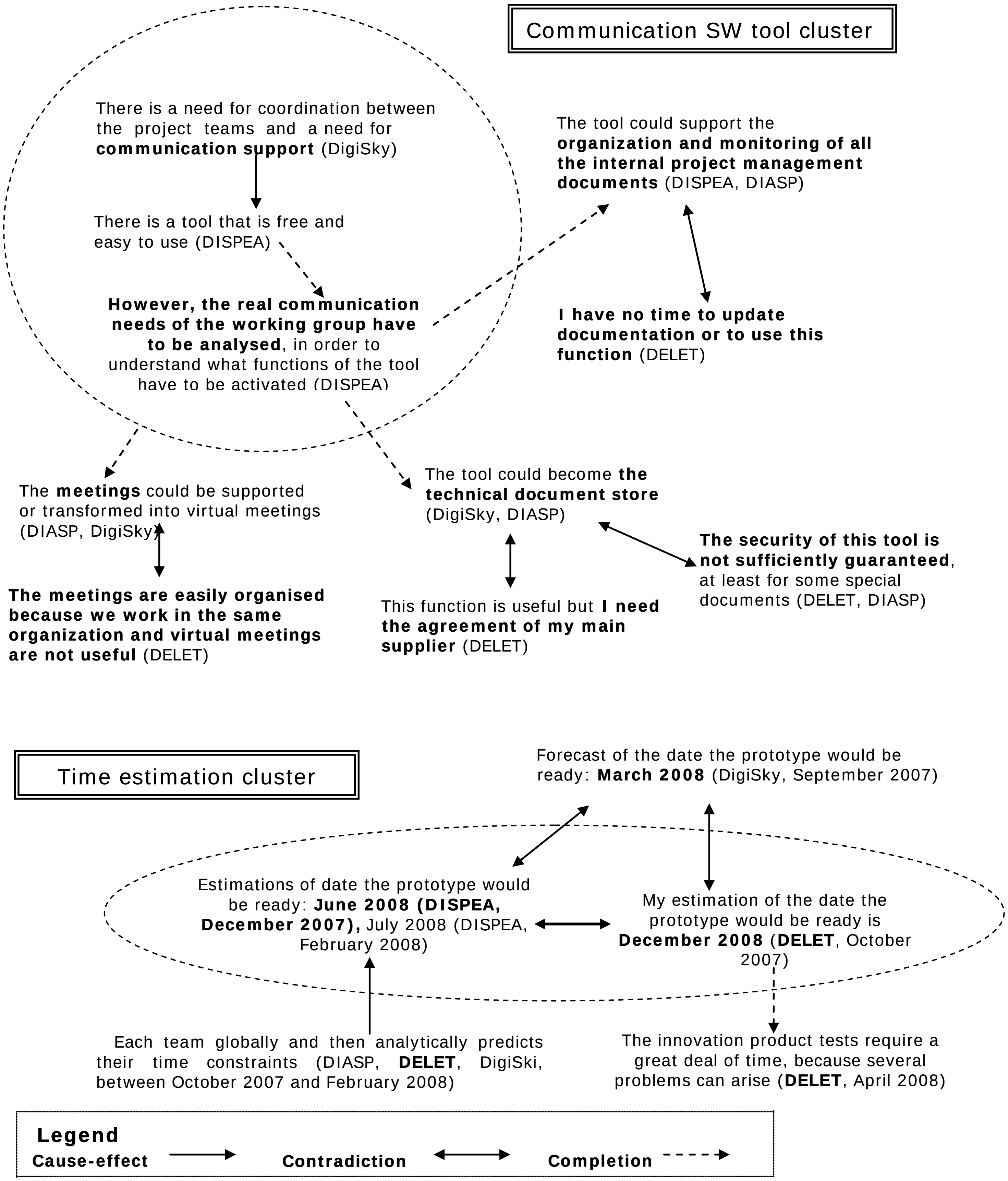

Fig. 4 - Representation networks: two clusters in relation to two sub-problems

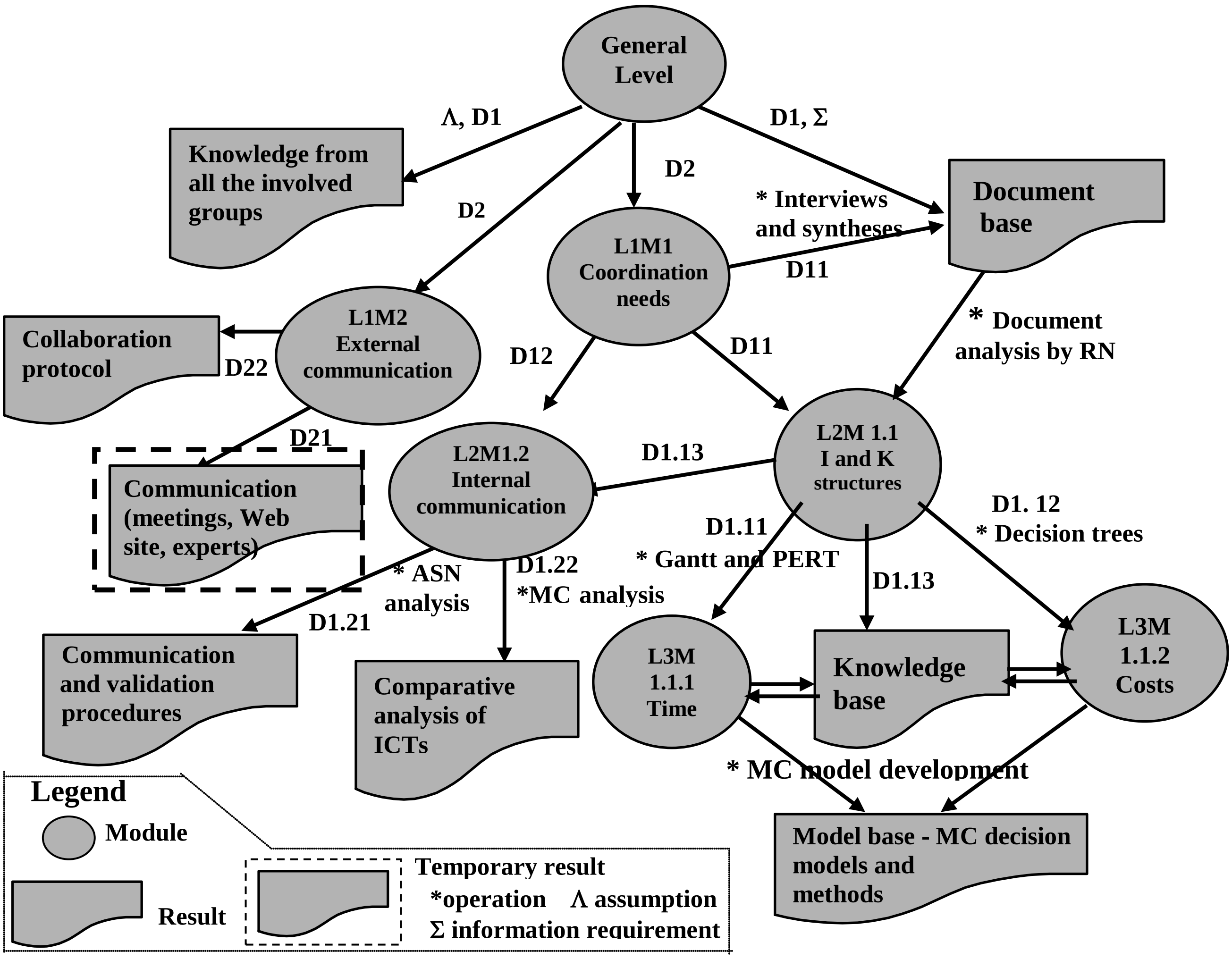

Fig. 5 - The intervention Map

Two structuring dimensions have been activated to control the recognized uncertainties and the first (D1) makes an assumption that stimulates some inquiring activities. Assumption Λ, which is a result of the uncertainty analysis which was conducted together with the coordinators, is "the specific elements of the project have to be analysed from the different points of view of the involved units". The activation of a set of interviews, to directly obtain information on the different points of view (Σ in figure 5), is connected to assumption Λ. The interviews, but also the syntheses of all the themes that are discussed in the meetings, have to be inserted into a structured Document base.

The second dimension, D2, activates the second level of the Multilevel Schema, where the needs for "coordination" that the promoters express at the start, in relation to the nature of the project, have to be analysed in one specific module (Level 1 Module 1, labelled L1M1) while the needs for “communication towards external agents and new possible sponsors” have to be analysed at the same level, but in another module (L1M2).

The main problem dimensions in L1M2 are clear to the coordinators and are related to the uncertainty pertaining to the communication finalities and tools, the need for experts (above all in the sponsor acquisition activities) and the interaction modalities with the experts. The first structuring dimension of the L1M2 module (D21) defines some communication modalities, such as a periodical meeting with all the involved technological and financial sponsors, and the development of a Web site. The second model dimension, D22, activates a support activity in the development of a collaboration protocol between the Politecnico di Torino and DigiSky, in order to improve the visibility of the project.

The main dimensions of the “Needs for project coordination” problem are identified with the coordinators and expressed in the L1M1 module. These dimensions refer to the distribution of global knowledge among the several people involved with different competencies, the fact that a local decision can have an impact on other decisions at a local or global level, and the idea that some local decisions could have been made but not communicated, to the others in the group. In order to face these sub-problems, the first structuring dimension of the L1M1 module (D11) defines the content and the aims of the interviews, which have to be conducted and inserted into the Document base, and the need for a synthesis of the Document base, after each meeting. The same dimension, D11, activates the third level of the Multilevel Schema, where the structured elements of the Document base have to be analysed and translated into information and knowledge structures (L2M1.1 module).

Each interview/synthesis of a meeting (from the Document base) has to be analysed separately, in order to identify its knowledge elements, and then a global synthesis of the documents is created and visualized as clusters of related concepts, using the Representation networks modality (RN in figure 5). The Representation networks in L2M1.1. (e.g. the two clusters in figure 4) are inserted into the Problem formulation. The coordinator group analyses each cluster that proposes multiple interpretations of the same topic or conflictual positions in relation to specific activities or strategies, with the aim of sub-problem identification and specific action planning and activation.

3.2 The coordination group and MACRAME

The first interviews to all the participants were analysed together with the coordinators in November and the first meeting, which involved all the project teams, was organised in December in order to discuss the main uncertainties that had emerged (and which are included in the problem formulation of L2M1.1) and the use of some tools to better control the process. A structured synthesis of the meetings was used to integrate the problem formulation of the L2M1.1 module and this allowed the coordination group to analyse the problem situation.

The first problem dimension of the L2M1.1 module resulted in uncertainty concerning the time that each activity of each project unit would require and the inconsistent previsions (in one case from the same DELET unit, see the second cluster in figure 4) about the overall time required to build the prototype for its final test. The second dimension resulted in uncertainty concerning the costs and the risks of the different activities.

The D1.11 structuring dimension activated a Gantt scheme in relation to the first uncertainty. In this case, the tool assumes the role of a data acquisition and structuring procedure, which is used to stimulate a more analytical definition of all the activities and their times. The Microsoft SW Project package was initially considered to be too complicated, but instead resulted to be simple and sufficiently adequate for the project.

The second uncertainty required another data acquisition and structuring procedure (which D1.12 activated to face the "make or buy" decision problem) and the use of decision trees. When two options (making a prototype component, such as an electric engine, an automatic control system or a simple prop for the hydrogen fuel cells, or buying the same component) are recognized to be possible in a project unit, they have to be analysed, at least in terms of costs, times and risks, and not only at the unit level. These options have to be combined with all the other 'make or buy' problem options, in all the other project units, and with the other possible decisions (e.g. possible suppliers, numbers and dimension of the fuel cells, specific electronics devices), in order to have a global vision of how many and what the different decision alternatives are. The decision trees were used to synthesize and describe the different local or global decisions.

3.3 Integration and validation of knowledge elements to support decision

The D1.11 and D1.12 structuring dimensions also activated two new modules where all the results of the different activities and tools were collectively analysed in order to produce new knowledge elements, and were analytically synthesized to make decisions.

The third dimension, D1.13, defines the need for a Knowledge base. It includes all the elements that were elaborated in the L2M1.1 module and the new ones from the L3M1.1.1 and L3M1.1.2 modules. These elements were used to define some multicriteria models, where the costs (which can also include the risks) that are associated to each alternative decision are analysed in detail and evaluated with all the other aspects, or consequences, that can distinguish them. Multicriteria methods were proposed to compare and rank the alternative decisions. Multicriteria models (and applications of the methods to the models) are included in the Model base. The structuring dimension, D1.13, also suggests the sharing of some Knowledge base elements using an SW communication tool.

D11, the L1M1second structuring dimension, activated the L2M1.1 module and D12 underlined the need for an initial validation of all the acquired knowledge elements, when they are structured in the Representation networks. To activate this process, these knowledge elements always have to be transferred to the project coordination team and then to the other components of the project team by communication protocols that have to be defined at the third level by the L2M1.2 module. The analysis of the Actor Structure Network (ASN in figure 5) facilitates the definition of all the actors' roles and functions in the communication network.

The L2M1.2 module deals with uncertainty concerning the structuring of a communication plan and the choice of supporting tools. The D1.21 structuring dimension activates data and document communication procedures, in relation to both uncertainties, in order to obtain an internal validation or the identification of critical interpretations or misunderstandings. The D1.22 dimension activates a comparative information and communication technology analysis, in relation to different use hypotheses.

3.4 Results

At the end of an action research intervention, a Document base was structured in order to include all the documents from the involved units. This can be considered a first result. A second result is that the Mayetic Village was chosen as the communication tool and, at the same time, the suggestion was made to use the communication channels that the intervention had opened. Communication protocols, between the group and the external agents and between the project coordinators and the teams, were defined. Uncertainty about the project development time still remained, but the situation was partially under control. The costs and risks that can be associated to some alternative decisions (including "buy or make" possibilities) have been evaluated, but the main result is that the evaluation procedure is now used on a regular basis by the coordination team. The results, in terms of web site development and communication with the marketing experts, have been considered to be only partial and temporary because they are evolving continuously. The DISPEA unit is currently only involved in these activities.

The action research intervention was started in September 2007 and finished in July 2008, when the main decision was made that DELET would design a very light electric engine, with a new structural concept that would suit all the other project requirements. The months between July 2008 and June 2009 were used to complete and test the electronic devices and the automatic control systems and to develop the new engine. SicmeMotori, a partner that has been present from the beginning, produced and tested the engine.

The speed record for the light aircraft class was achieved during the WAG in Turin, in June 2009, but with electric propulsion. At present Sky-Spark still only has electric propulsion (75 KW batteries), but the tests on the hydrogen fuel cells, which were conducted in the EnviPark laboratory under the supervision of the Politecnico di Torino, have finished and the first piloted flight, with complete electric propulsion and energy derived from hydrogen fuel cells, is scheduled for the near future.

4. Conclusive remarks

Researchers from different Departments at the Politecnico di Torino and DigiSky, a start-up company from the internal incubator, have collaborated to produce an innovative light aircraft (Sky-Spark) that utilizes hydrogen as fuel.

An action research intervention was required and activated to analyse the project development context in detail, in order to reduce organizational complexity and uncertainty and to manage innovative and unstructured situations. An approach which integrates problem structuring and analytical tools in decision aiding procedures has been adopted. It allows some knowledge elements to be acquired and structured and new knowledge representations to be progressively created and proposed in validation and communication contexts, in order to become shared and operational.

The intervention required three months to understand the situation, identify and communicate the critical elements and activate some knowledge acquisition and structuring tools, and then six months to apply the tools, in order to produce validated knowledge and to transfer the procedures to the coordination group. The coordinators considered the intervention essential “to avoid the risk of converging towards a blind alley” and to overcome the critical lack of operational communication in the project. A communication space was elaborated, for the first time, six months after the project was started, and it was used to critically analyse the project uncertainties and the temporary results, to identify weaknesses and propose and discuss new activities.

The MACRAME methodology played two different roles in the project. At first MACRAME was used as an aid for the DISPEA unit, to orient and control the action research when the situation was not clear. MACRAME was then used to analyse the situation together with the coordination team and later together with the other units, in order to validate or improve the representations, to systematically read the main uncertainties and criticalities of the project and to collectively orient the action.

Some tools were particularly useful for proposing the acquired knowledge to the coordination group or to the project units. The Representation network, an internal MACRAME tool, facilitated the coordinators’ structured recognition of the different positions of the involved actors and a detailed analysis of each inconsistent or equivocal element. Gantt and Pert were proposed to all the units, both individually and in the meetings, using the Microsoft SW Project package. The tool was not used to manage the project, but resulted to be useful to obtain information from the units and then to improve their systemic view of the global project and the problem analysis during the meetings.

The Multilevel Schema and Map, other internal MACRAME tools, resulted to be useful above all for the students involved in the action research and helped them recognize their role and reflect on their experience. These tools offer both a global view of the problem structure and the possibility of navigating through the Schema modules in order to analyse, discuss and change some basic elements of the problem. The Map also offers a synthetic description of how the other tools are integrated in a communication space to underline problems, structure decision models, and elaborate alternative solutions and then propose them for collective evaluations and decisions. In this intervention, the Multilevel Schema and Map have become a structured way of documenting the activities, mistakes and results.

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