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A system to integrate unstructured or semi-structured information resources: an application in a process of innovation design

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Abstract. A system that integrates different tools, from multicriteria analysis and mathematical programming but also cognitive and social psychology, can be proposed to cope with complexities and uncertainties that generate criticality in the socio technical approach. The purpose of this paper is to examine the potentialities of this system, above all in terms of information fusion and use in various contexts, and to propose an application in relation to an industrial project, in order to support the conceptual phase of the design processre.

Keywords. conceptual and contextual representations, complex factors incorporating and control, problem formulation and structuring, conceptual design

Introduction

Socio-technical systems, where technological components are inter-related with the complexity that is generated by individual or organizational actions and processes, present several methodological problems. Many of the involved factors are not meaningfully quantifiable, since they are connected to technological but also to social, organizational and political dimensions. Everything is connected to everything else and "what might seem to be the most marginal of factors can, under the right circumstances, become a dominating force of change" [1]. Multiple actors and perspectives, competitive or conflicting interests, constraints and uncertainties (that, using the distinction proposed in [2], can be connected to the working environment, the related decision fields and/or the guiding values) can generate what [3] define an unstructured problem.

Without identification and control of uncertainty and complexity the decision could be difficult or impossible and in some cases also the decision problem is not clearly formulated and has to be structured.

Human cognitive deficiencies could be reduced by integrating various sources of information, providing intelligent access to relevant knowledge and aiding the process of problem structuring. Acquiring and organizing knowledge and information elements from different sources and with different conceptual and contextual representations can

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be essential not only to understand but also to reduce or control complexity and uncertainty and therefore to orient analysis, decision and action.

The aim of this work is to propose a system that integrates different tools, from disciplines such as cognitive and social psychology but also operations research, in order to identify and analyze complex factors and introduce them in the decision process, in a formal way that has to be consistent with the context and easy to be used in elaboration, evaluation and choice of decision alternatives.

The system was applied in relation to a process of innovation design to reduce uncertainty in the phase of conceptual design and to identify and underline complexities starting from information resources that often are underestimate for their fragmentation and low level of structuring. Trough an integrated use of actor analysis and cognitive mapping, profiles of the potential users were elaborated and their requirements acquired and formalized, but also organization, technological and economical constraints, to the innovation implementation, were identified.

An integration of soft and traditional OR (Operations Research) tools, with others from different disciplines, allowed extraction of knowledge from several different sources to be done and the results moved in formal models of linear programming and multiple criteria that the actors of the design process can use.

The system is described in the first section and the problem context that generated the application in the second. The last section proposes our test of the integrated use of the tools in the decision support system by the procedure that was adopted in the application and some results.

1. The system

First The sociological and psychological literatures suggest approaches and methodological tools to identify complexities and uncertainties and cope with. Logical and structured procedures are also proposed in the Operations Research (OR) literature as “soft OR methods or problem structuring methods (PSM)”, to facilitate a shared vision of the situation and to decide how complexities and uncertainties have to be controlled and improvement actions to be elaborated, evaluated, validated and implemented. PSM could be improved by an integrated and interdisciplinary approach, see for instance [4], that systematically helps in identifying or constructing an agreed framework for the problem formulation, above all when the situation is “new”.

Methods of actor network analysis could be essential to analyze problems that are characterized by multiple actors, perspectives, experiences and competing interests. They can be proposed in order to study the structure of the decision context where the individual/organizational actors (or the potential actors) play a role (or multiple roles) and activate relationships, to analyze their points of view and identify new potential actors or to understand and reduce organizational complexity. Different approaches are proposed in literature and the selection of a method, in relation to a specific problem, is complicated by the fact that different methods till now have not been applied for the same multi-actor problem and compared [5] .

Actor network theory and social network analysis are proposed by socio-psychology literature [6], [7] and [8] for the social structure analysis and, specifically, the investigation of the structure relational aspects [9] that originate success or failure of the organizations. In the context of Strategic Management, Stakeholder Theory [10] manages and integrates relationships and interests of shareholders, employees, customers, suppliers, communities, and other groups in a way that ensures the long-term success of the firm [11]. In the Operations Research context, some methodologies aim to capture the actors' perception of the problem, to orchestrate discussions and negotiate consensus on a course of action to be taken [12] and [3]. Metagame theory [13] and [14] is a reconstruction of game theory on a non-quantitative basis and reflects on a problem in terms of decision issues and stakeholders who may exert different options to gain control over these issues. MESSII [15] wants to investigate or favour the development of an interaction space, i.e. an interorganizational informal structure which facilitates communication among organizations in complex problem. Interactions between actors are possible in this space and can be regulated to integrate and legitimate behaviour and to reduce uncertainty. Problem formulation [16] is a structuring methodology based on the concept that "a problem has to be described as a number of inter-related systems" that can be organizations, specific components of these organizations or individuals. In the Information systems research, [17] proposed in a seminal article the idea of computer technology as social organization and introduced a framework for understanding the impact of information technology on business processes by the analysis of two specific "computing webs", the first focalizing on the technology and the second on the involved actors. They defined this analysis as Socio-technical design. The interactions between a user (or an actor) and the context are often described and analyzed using UML language (and specifically Use Case Diagram) both in the practice and in several disciplines, from Software engineering to Systems engineering.

Cognitive approaches and mapping techniques showing cognitive structures and reflecting values, emotions and behaviours can be used to acquire, synthesize, code and communicate all the elements that come from the different points of view of the actors who are involved at different levels in a cognitive or a decision process. Cognitive mapping aims to provide a tool for revealing subjective beliefs in a meaningful way so that they can be examined not only by the individual for whom the map is constructed, but also by other individuals and groups [18], [19] and [3]. Several typologies of map (different in terms of reference theories, structure, content and its main sources, context of use and main aims) are proposed in literature and used to depict, structure and face complex issues. Conceptual maps [20] explore individual knowledge, to represent and communicate expert knowledge and create new knowledge. Casual maps [18] are useful to the organizations in the context of strategic management, in order to diagnose the reasons for unsatisfactory and satisfactory outcomes at the end of a project, or to facilitate risk analysis for future projects helping the actors' identification and control of potential difficulties, at the beginning of a project. Argument maps [21] and [22] support the analysis of pros and cons in business settings. Mind and semantic maps [23] are used to generate, visualize, structure and classify ideas, explain concepts behind words, associations and diachronic purposes and to predict language change. Knowledge maps [24] and [25] elicit, code, visualize, share, use and expand knowledge. Topic maps [26] and [27] put the emphasis on information "findability", i.e. how information that is contained on a website can be found.

The integration of actors analysis methods and cognitive mapping techniques could enrich or complete the vision of the whole situation and produce knowledge elements that are useful to reduce uncertainty about the cognitive aspects of the specific working environment and about values and roles of the individual or organization actors. Actor analysis methods can be used to understand the context, but also to identify actors who could be involved and to capture and represent differing perceptions of the situation and some specific (central or marginal) problem formulations. The knowledge elements that come from the cognitive maps that synthesize the actors' points of view could also be used to improve the actor analysis (proposing, for exempla, new activities or actors, and related complex issues, to be analyzed). The actor network knowledge can facilitate the analysis of the actors' points of view, when they propose less clear or contradictory concepts that have to be analyzed by cognitive maps. The effectiveness of each method can be improved by the integration of a "complementary" method (see figure 1).

Figure 1. Integration of actor analysis and cognitive mapping in a learning cycle that improves the analysis

When this integration is made and a clearer idea of the problem is acquired, a second integration step involves some classical OR methods (in particular mathematical programming and multiple criteria decision analysis). Concepts and relationships, that were previously acquired from different sources and structured and synthesized by actor networks and cognitive maps, are transformed into formal models, with objectives, variables, constraints and parameters or actions (strategies or courses of actions to be activated), evaluation criteria and parameters that express preferences. Methods are applied in order to elaborate possible solutions and compare them, or to modify the models identifying new aspects or points of view or key actors.

"Cycling between modeling approaches gave benefits that could not have been attained by either hard or soft modeling in isolation" [28]. This "two steps" integration process is not linear but, as a learning cycle, better defines the knowledge elements that are essential in a specific context and improves communication and modeling. The logical representation of the cycles is proposed in figure 2.

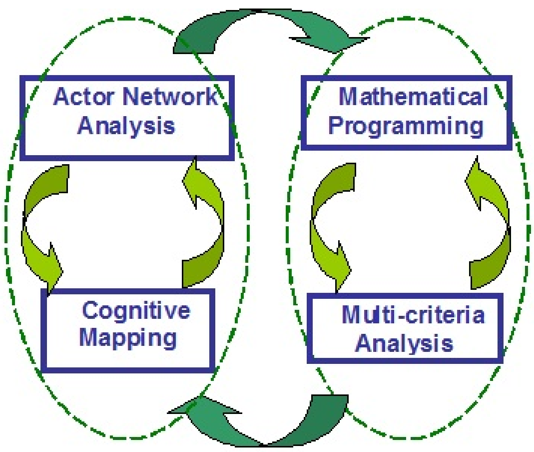

Figure 2. System as a learning cycle

Structured, partially structured and unstructured knowledge elements are acquired from different sources and soft and hard decision aiding tools are used to synthesize these elements maintaining the view of each actor explicit. An overall schema is developed synthesizing the global view, analysing uncertainties, contradictions and semantic conflicts and underlining similar positions and fundamental dimensions of the problem. The overall scheme can suggest a structure where some components of the problems become evident. The integration between tools is activated when knowledge is enough structured to deal a component by a formal model and an OR method. The results can be analysed and used in the real context or submitted to a new analysis cycle where the weak elements of the results orient a new broader and/or deeper analysis by the soft decision aiding tools.

An application of the decision support system in relation to an industrial research project was developed to identify and cope design problems, and to orient the conceptual design and the formal elaboration and evaluation of alternative solutions to specific problems. The context that generated the application and a general description of our approach are proposed in the next section.

2. The context and the adopted approach

An industrial research project, SMAT-F1, was activated in January 2009 as the first phase of the global project of a new advanced system to monitor the territory (the meaning of the acronym SMAT) and it was financed by a public institution, the Piedmont Region. The project involved several enterprises and some research units of the Politecnico di Torino and the University of Turin, under the leadership of Alenia Aeronautica, a company which is active in the aeronautical military and civil markets.

The purpose of SMAT-F1, that was completed at the end of 2011, is to test the performances of three legacy Unmanned Aerial Vehicles (UAVs), working as an integrated monitoring system, and to identify all the specific innovations that have to be introduced, in terms of control stations, sensors for specific data acquisitions and communication systems for data transmission even in critical situations, in order to guarantee a civil use of this system.

In the first phase of the project, the aim of our research unit was the identification of the organisations that could become the clients of a new monitoring service and the analysis of their monitoring needs, for the test of the legacy UAVs, but above all for the future phases of the SMAT project, when the innovation should be designed and implemented.

Overall in aeronautics, where many years are required not only to create a new aircraft but also to innovate some elements of a legacy system, clearly understanding the points of view of the potential users of a new system is essential to identify and structure the requirements that orient the project. In this case, the key actors of the current land monitoring processes are some of the potential users of the SMAT technology and recording and tracking their points of view could be important to understand the situation and also to involve some of them, in the future, in a decisional structure that should facilitate the design of both the innovative system and the new monitoring service.

A correct acquisition of their points of view needs understanding and control of some uncertainties that are connected to the validity of the acquired knowledge (e.g. in terms of reliability, consistency, completeness), to the value systems of the key actors and to the nature of the relationships between the organizations that are involved in land monitoring processes. Open interviews, starting from a framework of key questions, are more useful than a questionnaire to underline and clarify these uncertainty elements and to obtain an idea of what the knowledge elements that have to be acquired and analysed are.

Forty-nine potential users were identified and interviewed, in order to collect knowledge elements about their monitoring needs and their points of view in relation to gaps of the present monitoring activities or uncertainties about the new system. Starting from the validated interviews and the knowledge elements that the survey has acquired also from experts and literature, a data base was developed and some tables organized to synthesize all the structured or partially structured data (land monitoring current activities and characteristics, such as cost and required quality; monitoring needs and factors that should characterize the monitoring activities; list of the possible uses of SMAT). Then a clustering approach was used for the definition of land monitoring categories (or macro activities) and the assignment of all the expressed needs to these categories. The proximity of the needs, that were expressed during the interviews in relation to the identified categories, was maximized and the number of the basic activities that synthesize similar needs was minimized.

The completeness of this first result, in terms of macro and basic activities, and the consistency of the clustering approach were tested by the data base. The last activity with the structured knowledge elements consisted in the definition of the main parameters that allow the basic activities to be described[2].

Actor analysis and cognitive mapping were activated to deal with the partially structured (e.g. actors who have been mentioned and indications about their role in the current processes) or unstructured knowledge elements (above all opinions about specific themes) that emerged from the interviews and the analysis of the different organizations who are involved in the land monitoring processes.

This second analysis was developed to structure all these elements and clarify uncertainties and contradictions that the survey has underlined, in order to visualize the organization complexity that is associated to the monitoring processes. The integration of actor network techniques and cognitive maps was used to validate the collected information and verify the reliability of the sources and their skills, to support identification, formulation and structuring of specific problems, that are above all connected to the expressed uncertainties, and to identify constraints, opportunities and elements of the preference systems that define frameworks and parameters of models.

All the acquired knowledge elements were used in the SMAT-F1 project but they can facilitate communication, organizational learning and decision in the future phases of the project.

The analysis of a map, that is a model of action-orientated thinking, can clarify the semantic meaning of a specific problem, a relation between actors or an actor role. Actor networks are easily used for the definition of the actors who have to be involved in the future phases, at different levels. Constraints to the new acquisition and use of data can be better understood if they are used in formal models of mathematical programming, because they can limit the decision space in the design process. When a

[2] The five macro and the eighteen basic activities were described in tables by the timing requirements of each monitoring activity (such as frequency, nature of the notice, duration of the event and time constraints that are imposed on the data receipt), the spatial characteristics of each activity target area and the nature of the required data, with acquisition details and level of confidence of the acquisition.

plurality of solutions is admissible, the decision can be facilitated if some preference systems, that the interviews have captured, are formalised in multicriteria models.

The same knowledge structures that were used in SMAT-F1 could activate a learning cycle, in the next phase of SMAT project, where the possible problems can be analysed from different points of view and their (formal) representation changed, improved or shared in a decision context where the individual/organizational actors play a role consistent with the (visualized) decision space.

In the next section some examples of the tools application and some results are proposed.

3. Examples and results of the adopted procedure

An integrated analysis of concepts and actor networks allowed an enough clear idea of some central problems in the SMAT project. This “idea” is synthesized by schemes that include several elements: the main constraints that today limit some monitoring activities, but also the constraints that could limit the innovation process, the aspects that could positively or negatively affect the adoption of new procedures, i.e. the benefits that are expected but also the main risks that are perceived as evident in the change process that should characterize some situations, and the space of action of some potential users who should be involved as actors in the next phases of the project.

Classical OR methods (in particular mathematical programming and multiple criteria decision analysis, as they were used also in [29]) could be used in the future phases of the project to allow the actors to deal with some specific problems, in conditions of reduced uncertainty and with a whole vision of the problems that could impact the design process, where all the main specific difficulties are explicitly included.

3.1. The integration of knowledge elements from several organisation sources

The organisations developing monitoring activities (data acquisition, treatment, transfer or use) were considered potential users of SMAT, the new monitoring system of the industrial project. A first synthetic actor network was defined by the first interview to a director of the Turin Provincial Authority. Then each new interview allowed actors, who are involved in land monitoring processes with different roles, to be added to the list of organizations to be contacted. Identification and understanding of the working relationships between these actors were sometimes difficult when the interview indications resulted not clear enough. A specific analysis of the official functions of these organisations was used to upgrade the original actor network and to create new networks in relation to some actors who are used to coordinate their activities. An example of these networks is proposed in figure 3 and includes the main actors who are involved in the monitoring context “natural risk assessment, forecast, prevention and management”, all the interviewed actors who are the knowledge sources in relation to this context and the other who were mentioned during the interviews, as involved in the context monitoring processes.

All the technologies that were mentioned and described during the interviews (information systems, inventories, models, public registers, communication technologies and so on) are included in the network as *non human actors*, terminology that was proposed in Actor Network Theory [6] to define and analyse this kind of actors. Their role is important to understand which monitoring processes are today activated and which organizations are operationally involved, in order to identify a market for SMAT and its characteristics.

The arcs connect technology resources to the actors who can use or develop applications of these technologies or take charge of them. The arcs can also describe relationships between actors, such as information exchange, transfer of monetary resources, responsibility or specific actions such as delegation. In figure 3 an arc includes question marks, because this relationship was differently described in some interviews and the contradiction made evident in the cognitive map. Also some specific roles of the actors who are connected to the technologies resulted not so clear. In order to limit these uncertainties and better understand the whole situation, a deeper analysis (with experts and using the web site of the Civil Protection in Italy[3]) produced a new actor network structure that clarified the situation.

The integration of the actor analysis and cognitive mapping approaches reduced uncertainty in the survey, explained some contradictions and allowed completeness and reliability of the investigation to be verified.

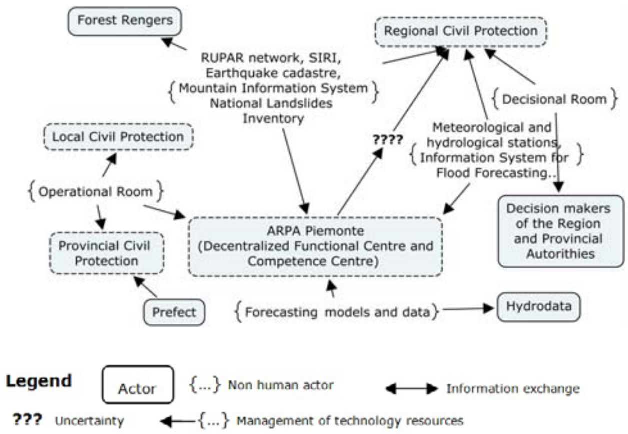

Figure 3. Actors in the context of prevention, prevision and management of natural risks

A specific technique of cognitive mapping, Representation networks, was adopted to synthesize and represent the knowledge elements that the interviews produced. Both technicians, with specific and various competencies, and managers, at different levels, were interviewed. They were required to describe monitoring needs that a new technology could satisfy. And they described the current monitoring activities in relation to different topics (agriculture, pollution, transport, waste, cartography, data updating, emergency situations, such as landslides and floods) and the main constraints that today limit some monitoring activities, the aspects that could positively or negatively affect the adoption of new procedures (expected benefits and perceived risks or criticalities), but also doubts and uncertainties about any organization change and some proposals to reduce these difficulties. Their points of view resulted sometimes unclear or contradictory. The knowledge elements that came from the interviews

[3] Italian Civil Protection, http://ec.europa.eu/echo/civil_protection/vademecum/it/2-it-1.html

sometimes presented interpretative uncertainties and produced methodological questions.

By Representation network, the cognitive mapping tool of a problem structuring method that was proposed in [30] and [31], the unstructured knowledge elements, from the validated interviews, are organized in statements, coded and synthesized in concepts, that are clustered and connected by logical relationships[4]. The representation networks of figure 4 are cognitive maps that were developed in the project in relation to the same monitoring context “natural risk assessment, forecast, prevention and management”. Each map proposes the different points of view of the interviewed people in relation to a specific topic (that a cluster of concepts in proximity relation has identified). All the nodes are concepts that were expressed during the interviews by a source who is indicated in brackets. These sources correspond with the actors of figure 3. The relationships between the concepts are the result of a logical analysis and can be different: cause and effect, specification, exemplification, contradiction and so on. Some links are of operational nature. They can make the need of new investigation activities explicit or connect a map with another representation network or suggest connections between concepts and possible elements of formal models, such as constraints, judgements, objectives, possible criteria, trade-off or relative importance of the proposed aspects. The other relationships facilitate the cognitive analysis and want to clarify too generic concepts or verify and explain better others that are too confused or underline uncertainties and apparent contradictions, that have to be deeply analyzed and reduced or understood.

The map of figure 4a is related to the topic Compatibility with the event timing and includes not only some time constraints, but also an uncertainty and a possible contradiction between expressions of these constraints. A contradiction between needs of flood monitoring is present, and more evident, in the representation network of figure 4b where the distinction between data and images is not always clear and proposes a possible misunderstanding about the terminology or the meaning of a need. Uncertainty and contradictions negatively impact each tentative of sizing the demand of innovation in the monitoring processes and, at the same time, limit the reliability of the sources. Uncertainties emerge from the interviews about two important actors of this context, ARPA Piedmont and Civil Protection of the Piedmont Region (PRCP). Heavy contradictions are underlined in the map of figure 4c between the concepts that synthesize their different roles and functions: the concepts in the left part of the network are in contradiction with the others in the right part. This contradiction, so evident that is underlined also in the actor network of figure 3, has been analysed with experts and using the web site of the Civil Protection in Italy, where the different organization levels of the Civil Protection (national, regional, provincial or local) and the roles of the actors of all the processes, not only in emergency conditions, but also in the prevision and prevention contexts, are described.

ARPA Piemonte (one of the main sources of the cognitive maps of figure 4 and a crucial actor in figure 3) is here described as one of the few decentralized functional centres of the national Department of Civil Protection and also a Competence Centre. Therefore ARPA Piemonte is not an “operational part of the Regional Civil Protection” in Piedmont and works in strict connection with the national Department of Civil Protection. This result, in terms of clarification of some heavy contradictions,

[4] The multi-step procedure is described with some details in [33]

becomes important also in terms of source reliability and facilitates the understanding of other apparent contradictions in the maps.

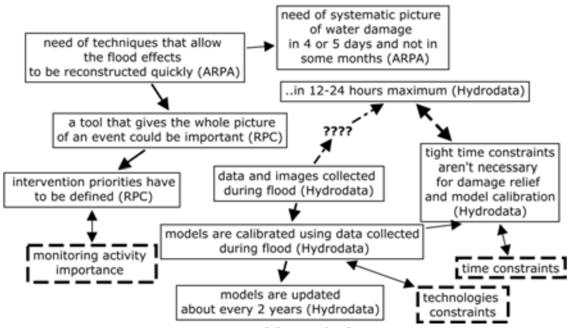

Figure 4a. Compatibly with the event timing

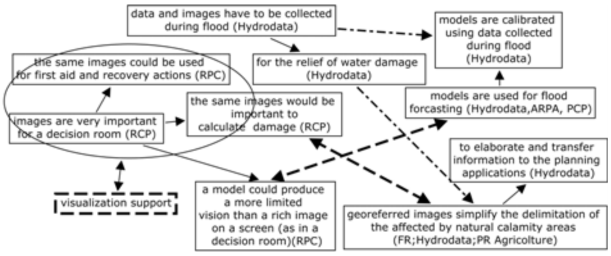

Figure 4b. Data or Images?

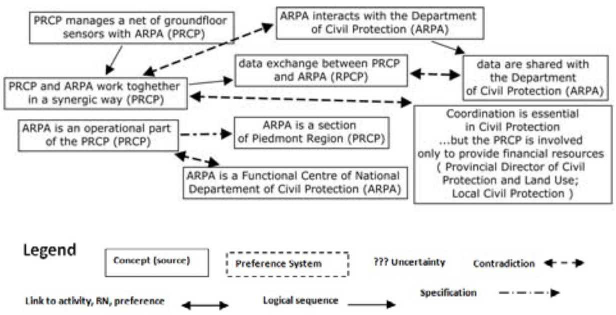

Figure 4c. Role and Relationships of ARPA and PRCP

3.2. Structuring a "multi-actor" preference system

Actor networks and cognitive maps have been created and used in the first phase of the project to reduce or control the uncertainty elements and to synthesize and visualize all the acquired knowledge elements about the central problems of the SMAT project.

The elements of a "multi-actor" preference system that the interviewed have expressed can be now structured by an integrated use of networks that can be easily proposed to support collaborative decision in the future phase of conceptual design. Some networks describe the overall multi-actor structure and the different specific contexts where involved actors expressed points of view and preferences in relation to an issue of the context. Others networks are cognitive maps that propose structures of concepts in relation to topics that can be central ideas, local problems or expressions of an emergent attitude towards changes.

Starting from these elements, model frameworks can be generated and used in a logic of action oriented thinking (see for instance the application that were described in [32], [29] and [33]) or oriented to the use of classical OR methods, to analyse each possible problem from all the relevant points of view and to elaborate, and criticize or evaluate, possible solutions. In a learning cycle the models can be discussed and redefine until the situation becomes clear enough.

A cluster of "similar" concepts, and then a representation network where the concepts are logically connected, can be created in the cognitive mapping process to synthesize the essential elements of a preference system in relation to a specific issue, and then to elaborate the components of a decision aiding formal model, such as goals and constraints, risks that cannot be accepted, importance of an aspect in relation to another, dimensions that express the structure of the evaluation model and criteria, to evaluate and compare alternative actions.

In relation to SMAT-F1, the first phase of the industrial project that was completed at the end of 2011, alternative design actions are not yet elaborated but model frameworks exist, in relation to some specific issues. When the analysed issue is the Organization of an effective monitoring activity, three model dimensions have been identified starting from all the concepts that are related to this specific topic, and some possible criteria can be identified and developed analysing the representation networks (some of them are proposed in the representation networks of figure 4a and 4b) or the structured data that are synthesized in the tables that describe the five macro activities and the eighteen base activities of monitoring. The model dimensions are:

- Flexibility (i.e. compatibility with the monitoring requests in terms of time and space; compatibility with the previous technologies and their results tat have to be upgraded),
- Payload adequacy to the requests (for example, sensors that are adequate to the operational requests but only certified sensors for some specific requests),
- Data handling and information processing consistency (in reply to requests of specific kinds of data[5] and level of confidence of each acquisition; of data storage capacity at long term; of specific alert systems or DSS).

If the problem is the definition of the *Critical factors that can determine a market for the innovative monitoring system*, a comparison between different existing monitoring technologies (satellites, helicopters, ground sensors, direct inspections and so on) with the innovative system could be useful. Several concepts emerged during the interviews in relation to this specific topic and a lot of different elements were proposed in relation to the *Cost* aspect. Analyzing together all these elements, two model dimensions (D1 Economical, D2 Technological) can be easily identified together with another less evident dimension. The Psychological dimension (D3) is related both to the concept of deterrent action (the surveillance, by SMAT or by satellites, is possible without to be visible) and pressure-anxiety reducing (the presence of a risk that has to be measured is

[5] Videos, graphic data (images and orthophotos), geographical data (topographic survey, site survey plan, DTM-Digital Terrain Models), SAR data (to assess physical conditions of an element, road, infrastructure, river, and/or to perform Coherent Change Detection), hyper spectral data (to recognize spectral signatures or to create a data base of spectral signatures) or other data from sensors (such as chemical sensors).

not stressed and put in evidence). The Technological dimension can be synthesized in the aspects Acquisition of data -When they need and - In the format that is required. The Economical dimension can be synthesized in the aspects Reduction of monitoring cost and Economies of scale creation. Each aspect has to be analysed and could be constructively transformed in one or more evaluation criteria.

An Organizational dimension could be present as D4, but it is related to the kind of service more than to the technology. A lot of concepts were expressed, in general, in relation to the need of an effective monitoring service. They can be defined proposals about the service organization and, in several cases, reference situations that have been described by examples, criticisms to the present organisation, constraints that the new organisation has to deal with or comparative judgements. Analyzing together these concepts and their relationships, *Organization of an effective monitoring service* becomes an important issue and its disaggregation in three sub problems or problem dimensions seems possible (the main aspects that are related to each dimension are listed in brackets):

- Coordination and control (Administrative coordination. Restriction forms to get to the service. End users' control of the procedures and/or the data quality),
- Integration (of data to be shared; of new projects of data acquisition and storage; of procedures of data transfer),
- Organizational complexity (Change as a consequence of the introduction of a new monitoring service. Resistance to change).

More specific elements should be used to define the evaluation criteria that multicriteria methods can use to compare alternative service organizations.

Table 1. Framework and models

<table>
<tr><th colspan="2">Economic/ Organizational Aspects</th><th colspan="2">Socio/Organizational Aspects</th><th colspan="2">Technological Aspects</th></tr>
<tr><td>How control costs</td><td>Air fleet definition</td><td>How the demand can be satisfied</td><td>Route definition</td><td>Performances of the system</td><td>Limits to the sensor use</td></tr>
<tr><td>Min Mission Time</td><td>Min Route</td><td>Max number of monitoring activities</td><td>Min sensor weights</td><td>Min number of UAV per mission</td><td>Min Workload</td></tr>
</table>

3.3. Mathematical programming to structure problems and models

Mathematical programming could be used in the future phases of the project to formally define constraints, elaborate admissible or efficient solutions and optimal solutions in relation to one or more objectives. Model frameworks also in this case can be generated and oriented to the development of formal models and to the use of OR methods. Table 1 proposes a general formulation of the SMAT problems, that includes economical and technical aspects, but also complexities at the organisation and at the social or individual level. The main factors that induce uncertainty and complexity are interrelated and each specific problem often presents more than one problematic aspect.

If the uncertainty elements are enough clarified and controlled a problem formulation process can start and define specific problems, such as Air fleet definition or How the demand can be satisfied that are listed at the second level of table 1, and some mathematical programming models, that are synthesized at the third level of the table in terms of kind of the objective function.

An example of problem formulation that uses the mathematical programming language is proposed in table 2. The objective function is "maximize the monitoring activities that the customers require (max the demand), in relation to the constraints on weight and volume of the sensors that have to be used". The constraints are defined in table 2 and the variables are defined as follows.

Given a set of sensors that can be used in different missions during a day (planning horizon), each data collection by a sensor j in time t becomes the 0-1 variable $x_{j,t}$, in a 0-1 linear program.

Given a single specific UAV, a limit on the weight P_j and the volume V_j of the sensors that can be transported is known.

An advantage matrix can synthesize the importance of the mission that is express by $w_{j,t}$ (all the requested images have not the same importance, each depends on client's priority, urgency of the demand and meteorological forecasts).

Each data typology must be acquired by one specific kind of sensor j (correspondence one-to-one sensor and data) and j=1,….,7. The time horizon of one shift is eight hours (the timeslots t) and t=1,….,7.

Table 2. A possible mathematical programming model

o.f.	$\max \sum_{j}^{n} \sum_{t}^{m} x_{j,t} w_{j,t}$	Max the weight demand
s.t.	$\sum_{j}^{n} x_{j,t} p_j = P \quad \forall t$	*Weight/volume constraints* The sum of the sensors' weights must be the max weight payload in every period
	$x_{j,t} \le x_{j,1} \quad \forall t_{/\{1\}} \forall j$	All the sensors that are on the UAV in t=1 are the same for the complete shift
	$\sum_{j}^{n} x_{j,t} v_j = V \quad \forall t$	The sum of the sensors' volumes must be the max weight payload in every period
	$\sum_{j}^{n} x_{j,t} = 1 \quad \forall t_2$	*Time constraints* For each timeslot t from t=2,…,7 exactly one sensor is retrieving data (example of possible request)
	$\sum_{j}^{n} \sum_{t}^{m} x_{j,t} \ge 6 \quad \forall j \ \forall t$ **(1)**	*Data acquisition constraints* In each timeslot t at least one sensor j is retrieving data (example of possible request)
	$\sum_{t}^{m} x_{j,t} \ge 2 \quad \forall j$	*Customer constraints* Each sensor must work at least in two timeslots (example of possible request)
	$\sum_{t}^{m} x_{A,t} \ge 1$	Sensor A must work at least in one timeslot (example of possible request)
	$x_{A,2} = 1$	Sensor A must work in timeslot 2 (example of possible request)

In relation to another problem formulation, in relation to a specific organization of the service with the aim of minimize staff shift and minimize the number of UAV for each mission, the model structure could be the same of the previous one, but with the introduction of the penalty concept (pen_j = penalty for each sensor) $\max \sum_{j}^{n} \sum_{t}^{m} x_{j,t} w_{j,t} - \sum_{j}^{n} pen$ (or only $\min \sum_{j}^{n} pen$).

In this case the previous constraints (1) becomes

$$\sum_{j}^{n} \sum_{t}^{m} x_{j,t} \ge 6 - \sum_{j}^{n} pen \ .$$

The concept of penalty is related to each sensor j. It is possible to built a matrix of weights for each sensor use that could be a function of the parameters that are related to the emergency context.

4. Conclusion

An intelligent use of tools from different disciplines can facilitate the integration of unstructured or semi - structured information resources and support individuals or groups of stakeholders within a complex environment, in order to understand a problem situation, agree a problem focus and make commitments to a set of actions. Conceptual representations of the acquired knowledge and information elements can be easily analysed and translated in context models, where the original elements and sources are always present but included in a whole vision of the context, and in partially structured frameworks and analytical models, when uncertainties and complexities that characterize the original information resources are clarified and/or reduced.

The final models can incorporate all the complex factors of the operating environment, because they are developed, with the involved actors or decision makers, cycling between different modeling approaches, but at the same time can be used to apply methods of multicriteria analysis and mathematical programming.

A sequence of "simulated" applications of the classical OR methods can be implemented, not as a problem solving approach but to activate new learning cycles that can facilitate the improvement of models, frameworks and, if it is required, also of problem description.

A system that includes tools from cognitive and social psychology and integrates them with models and methods of Operation Research is naturally oriented to the problem formulation and structuring context, as it is defined in [34] , [3] and [35]. An application in the first phase of a real process of innovation design allowed us to perceive an automatic attitude to negate the role of the "soft" tools by the side of the technicians, but at the same time communication was improved and the points of view of the end users were analysed, also when they proposed new complex elements and difficulties.

References

[1] T.Ritchey, Problem Structuring using computer-aided morphological analysis, *Journal of the Operational Research Society* **57** (2006), 792–801.

[2] J.Friend, The strategic choice approach. In: Rosenhead, J. (ed.) *Rational Analysis for a Problematic World,* Wiley, Chichester, 1989, 71-100.

[3] J.Rosenhead , J.Mingers, (eds.) *Rational Analysis for a Problematic World revisited*, Wiley, Chichester, 2001.

[4] C.Eden, Ackermann F., Where next for problem structuring methods?, *Journal of the Operational Research Society* **57** (2006), 766-768.

[5] J.Mingers, A classification of the philosophical assumptions of management science methods, *Journal of the Operational Research Society* **54** (2003), 559- 570.

[6] M.Callon, Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay. In: Law J. (ed.) *Power, Action and Belief: A New Sociology of Knowledge*, Routledge & Kegan Paul, London, 1986, 196-233.

[7] B. Latour, P.Mauguin, A Note on Socio-Technical Graphs, *Social Studies of Science* **22** (1992), 33-57.

[8] D.Banks, M.Carley, Models of Social Network Evolution, *Journal of Mathematical Sociology* **21** (1996), 173-196.

[9] S.Wasserman, K.Faust, *Social Network Analysis. Methods and Application*, Cambridge University Press, 1994.
[10] L.C.Freeman, A set of measures of centrality based on betweenness, *Sociometry* **40** (1984), 35-41.
[11] A.L.Friedman, Miles S. *Stakeholders: Theory and Practice*, Oxford University Press, 2006.
[12] U. Daellenbach., More thinking about Research Methods for the Resource-Based Perspective, *Strategic Management Journal* **23** (2002), 963-967.
[13] N.Howard, *Paradoxes of Rationality: Games, Metagames, and Political Behavior*, The MIT Press, Cambridge, 1971.
[14] N.Howard, The manager as politician and general: the metagame approach to analysing cooperation and conflict, In: Rosenhead J (ed.) Rational analysis for a problematic world, Wiley, Chichester, 1989, .
[15] A.Ostanello, A.Tsoukias, An explicative model of public interorganizational interactions, *Journal of the Operational Research Society* **70** (1993), 67-82.
[16] K.Bowen, An experiment in Problem Formulation, *The Journal of the Operational Research Society* **34** (1983), 685-694.
[17] R.Kling, W.Scacchi, The Web of Computing: Computing Technology as Social Organization, *Advances in Computers* **21** (1982), 333-345.
[18] C.Eden, Analyzing cognitive maps to help structure issues or problems, *European Journal Operational Research* **159** (2004), 673-686.
[19] C.Eden, On the nature of cognitive maps, *Journal of Management Studies* **29** (1992), 261- 266.
[20] J.D.Novak, How do we learn our lesson? Taking students through the process, *The Science Teacher* **60** (1993), 50-55.
[21] E.C.Tolman, Cognitive Maps in Rats and Men, *The Psychological Review* **55** (1948), 189-208.
[22] J.Horn, Human abilities: A review of research and theory in the early 1970's, *Annual Review of Psychology* **27**(1976), 437-485.
[23] T.Buzan, *The Mind Map Book*, BBC Books, London, 1993.
[24] E.W.Rogers, Why We Do Need to See Our knowledge?, *Knowledge Map* **1** (2000), 33-50.
[25] X. Stanford, What Is Knowledge Mapping?, *Knowledge Map*,**1** (2000), 67-79.
[26] N.S.Newcombe, N.Chiang, Learning information from hypothetical maps, *Memory and Cognition* **35** (2007), 895-909.
[27] S.Pepper, Euler, topic maps, and revolution, Proceedings of XML Europe, 1999, available on line at (19/11/2011) http://www.ontopia.net/topicmaps/materials/euler.pdf .
[28] F.Ackermann, C.Eden, T.M.Williams, A persuasive approach to delay and disruption using 'mixed methods', *Interfaces* **27** (1997), 48-65.
[29] M.F.Norese, E.Liguigli, C.Novello, Integrated use of linear programming and multiple criteria methods in an engineering design process, In: Carrea et al (eds.) *Placing humans at the center of knowledge, production and interaction networks*, Proceedings of the fourth workshop on Human Centered Processes, February 10-11, 2011, Genoa, 10-16.
[30] F.Buffa, G.Marzano, M.F.Norese, MACRAME: a modeling methodology in multiactor contexts, *Decision Support System* **17** (1996), 331-343.
[31] M.F.Norese, MACRAME: a problem formulation and model structuring assistant in multiactorial contexts, *Journal of the Operational Research Society* **84** (1995), 25-34.
[32] M.F.Norese, A process perspective and multicriteria approach in Decision-Aiding contexts, *Journal of Multi-Criteria Decision Analysis* **5** (1996), 133-144.
[33] M.F. Norese, F. Salassa, A System to Analyse Interviews and Structure the Acquired Knowledge Elements, In: Respício et al (eds.), *Bridging the Socio-technical Gap in Decision Support Systems - Challenges for the Next Decade*, IOS Press, Fairfax, 2010, 461-472.
[34] J. Rosenhead, (ed.) *Rational Analysis for a Problematic World: Problem Structuring Methods for Complexity, Uncertainty and Conflict*, Wiley, Chichester, 1989.
[35] V. Belton, T. Stewart, *Multiple criteria decision analysis: and integrated approach*, Kluwer Academic Publishers, Boston, 2002.