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DECISION AIDING TOOLS IN PRODUCT DEVELOPMENT: A CASE STUDY

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1. Introduction

The New Product Development (NPD) process is characterized by numerous elements of complexity and firms face varied challenges in managing NPD (Adler, 1995; Brown, Eisenhardt, 1995). Because of the close link with innovative processes and its multidisciplinary characteristics, the NPD needs tools and methodologies to acquire and structure the essential product knowledge elements and to define shared operative models. An extra attention has to be paid to the NPD process and call for new research in the NPD management to update and adapt methods and tools to the new industrial demand.
On the one hand, numerous models have been developed to define a paradigm of NPD process, and numerous contribution have studied the effective management of NPD projects or analyzed problems such as "design co-ordination" and knowledge management in design. On the other hand, all these theoretical elements have been confirmed from the industrial practice point of view, through new management perspectives on new product development processes (e.g. PLM), that, with their IT support systems (i.e. PDM, EKMS, etc…), are viewed as the way by which firms can support the NPD.
The focus of this work is the application of a integrated methodological approach in a Franco-Italian company of the aerospace industry. The company is partitioned into several business units and the Space Infrastructure and Transportation Business Unit (BUSIT) is here considered. This unit deals with the development of space modules for the International Space Station, re-entry vehicles, planetary exploration missions and some scientific satellites. The improvement of the NPD is focal for the company and some NPD management projects have been activated. These projects tends to identify and choose the right management tools and organize properly the processes and the communication. For this reason, the company requested a support to these projects in order to reach the comprehension of the communication and decisional mechanisms.
This work doesn't study project tasks or outcomes; it starts from the analysis of NPD phenomena to properly apply an approach which uses different perspectives and support tools to the NPD management. The elements of complexity of NPD in innovative contexts actually are suitable to be studied and modelled with integrated perspectives, especially in the early phases of the process, when the decisional situations are confused and their management could be chaotic. These elements of complexity are faced in the intervention and different "Contexts of Action" (Norese, Ostanello, 1988), which are recurring sequences of supporting activities with a unique objective, are associated to the NPD Management. The context of actions, oriented to different finalities, call for different support tools that are available in different ambits. In the intervention the tools are chosen in the Engineering Design, Project Management, and Management Science (MS)/Operation Research (OR).
The paper first section deals with a careful study of the BUSIT NPD by a synthesis model aimed to classify NPD situations in terms of complexity. The Hybrid Approach, its features and the

methodological general framework are discussed in the second section. The methodology for the identification of decisional and decision aiding (DA) processes is necessary for the Hybrid Approach application, but, in this work, it is mentioned and not carried out in detail (for a deeper study, see Montagna, 2007; Montagna, Norese 2008). The results of the analysis and one application that traces step by step the BUSIT process is discussed in the last section.

2. The elements of complexity of the NPD process

"Complexity" is surely a daily term in the engineering field. A mathematical complexity theory (the "Kolmogorov complexity") does exist in the computer science ambit and can be used to describe the complexity of a design (Suh, 2001), but it cannot be applied "as it is" by referring to "design" as the conceptual design stage of the NPD process.

The NPD is frequently described as an exercise in information processing (Adler, 1995; Eppinger, 1991; Tatikonda, Rosenthal, 2000) and organizational information processing theory is applied to describe it. In these contributions, uncertainty is considered but the definition of uncertainty, as the difference between the amount of information required and the amount already possessed (Galbraith, 1977), is not sufficient. Friend in 1989 identifies three typologies of uncertainty (Uncertainties on operating Environment (UE), Uncertainties on guiding Values (UV) and uncertainties on the Related decision fields (UR)) but only a typology (UE) refers to a lack of information. The presence of UE and UV uncertainties in the NPD requires exercises of objective clarification and answers in terms of "exploration of the interconnected decisions".

For these reasons, the elements of complexity of the NPD are here analyzed by analogy with a model (Marzano, et al., 1998) that defines the elements of complexity of a problematic situation for the analyst in a DA intervention. According to it, each complexity dimension of the NPD represents an element that contributes to the generation of the complexity of the process and can be considered as an axis of the complexity space of the NPD. Different typological situations can be located on each axis and each point in the NPD complexity space represents a possible operative situation whose position on the axis defines the uncertainty level. Four dimensions, whose axes are orientated following the ascending direction of the uncertainty level, are defined. The characterization of the BUSIT NPD can be provided with the described model and the BUSIT profile is represented in Figure 1.

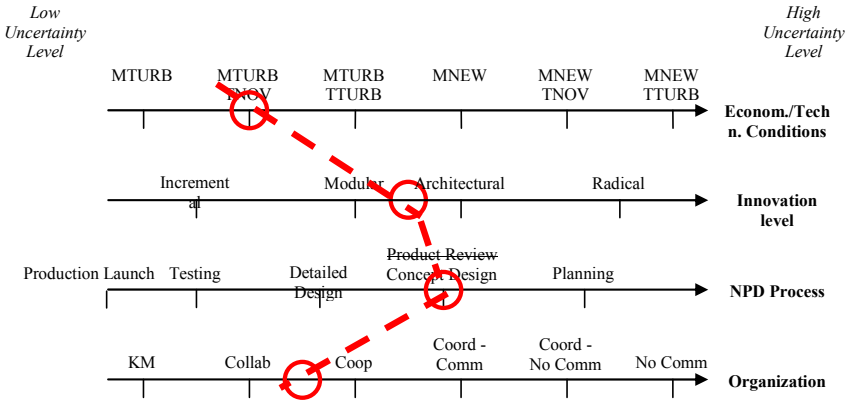

Figure 1. The synthesis model for the classification of NPD situations applied on BUSIT case

The first dimension can be associated to the economic and technological environmental conditions the firm operates in. Although some authors (Tatikonda, Rosenthal, 2000) don't consider the external conditions as important in project's technological challenges or project execution, in this model they are considered relevant because they define the most uncertainty elements on guiding values (UV), influence the design goals and are determinant in the early stages of the NPD. This first dimension

refers to the classification of Chen, Reilly and Lynn in (Chen, et al., 2005) for the identification of the different situations a firm could face (that are not situations where firms want to introduce innovative changes) and the four typologies (Market turbulence (MTURB), Technological novelty (TNOV), Market newness (MNEW), Technological turbulence (TTURB)) are combined in the resulting six typological situations. The six situations can be placed on the environmental axis with different uncertainty levels, as shown in Figure 1. Situation with no changes in the market or technologies are possible and are located at the origins of the space.

The BUSIT position on the first axis stands on the MTURB/TNOV point. This is due to a reference market that is strongly influenced by the political events in contrast with NPD processes that are oriented to long-term objectives. From a technological perspective, several innovations are implemented in the aerospace ambit but they never define turbulent situation because the severe reliability levels require long and deep development periods not achievable in uncertain contexts.

The second dimension is associated to product innovation. The Henderson and Clark (Henderson, Clark, 1990) taxonomy provides two aspects related to technologies and product component configurations and define four situations: "incremental", modular", "architectural" and "radical" innovations. Radical innovations are certainly rare and represent the most uncertain situations in the complexity space.

On this axis the situation of the considered company's products is controversial and it depends on the product typology (e.g. telecommunication satellites usually have incremental innovations, scientific ones require radical innovation due to the experimental nature). When the intervention took place, the situation stood between modular and architectural innovations but, for the future, radical innovations could be attended.

The third dimension is associated to the NPD and its phases. The reference for the NPD phases are the ISO 9001 and ISO TR 14062 norms. The considered phases (i.e. Planning, Concept Design, Detailed Design, Testing, Production Launch, and Product Review) can be ordered by the presence of less, or more, complex decisional processes, with different levels of associated uncertainty (Montagna, 2005). This order changes case by case and depends from the nature of the company.

In this case, the first NPD phase (Planning) is characterized by several uncertainty elements (e.g. new technologies, organizational targets and values, etc.) and the decisional process is complex and has to face unstructured situations. The second phase (Concept design) and the third phase are less uncertain (some elements are solved in the previous phases). The fourth phase is the Testing phase and most of the uncertainties are solved. The specific features of space infrastructure and re-entry vehicles oblige to reach the Production Launch (fifth phase) with no uncertainties concerning on the project and the production planes and it must be considered at the origins of the complexity space. Finally, the usual Product Review phase doesn't exist for aerospace vehicles because of the oneness of the product and it can be not considered in the model. Most projects, in which the BUSIT unit operates when the intervention took place, were in the Concept Design phase.

The last dimension is the organizational context. It is possible to identify some situations with different uncertainty levels (Montagna, 2005). The communication absence situation (No Com) is the most chaotic and uncertain. Communication, in fact, is the basis of coordination, cooperation and collaboration in the organizational activities. When institutions in charge of coordination are present in the firms, but in the operative activities there is no careful management of information and the coordination is therefore more difficult, situations are labelled "Coord/No Com". Where communication and coordination exist (Coord/Com), cooperation and collaboration are possible, but not always present. If collaboration implies more willingness and readiness of the actors than cooperation, collaborative situations (Collab) are less complex to manage than cooperative situations (Coop). When a firm really puts knowledge management into action, all the other conditions are present and this situation (KM) is the easiest and the less uncertain situation.

The organizational context in BUSIT is characterized by teams external and internal to the organization. Human resources are quite homogeneous, typically composed by aerospace, nuclear and mechanical engineers who already have a common language. Moreover, the long collaboration periods due to the high average seniority within the company further increase the internal communication. The organizational structure is characterized by several coordinators for each function (both about

engineering and management) so that communication and collaboration are facilitated. Concerning on the relations with the partners, some difficulties could exist for the realization of an optimal collaboration because of the organizational differences and the different objectives. In general, the management of knowledge is structured but not always formalized. The oneness of the projects that require a continuous tailoring of the NPD process, do not allow a detailed mapping of the activities and so only a coarse map is possible and only the single experts know the detailed activities. The seniority of resources helps dealing with the problem of poor codified knowledge but the long duration of the projects and the possibly faster turn-over of the resources could be critical. The BUSIT situation is then considered between cooperative and collaborative situations.
The fourth dimension is extremely important because it is responsible for the presence of procedural and organizational problems in the NPD process. When innovation implies the need for good knowledge of the whole system, and significant changes in the process and in the procedures, the NPD management become more complex and the control of the NPD projects fundamental. The integration of different methods, tools and technology in a decision aiding procedure can be useful. For this reason, an approach that considers all these factors could mitigate problems and support the NPD process and its management and control.

3. The Hybrid-approach and the research methodology

If innovative situations are complex and uncertain, an integrated perspective whose focus is on external and internal environments, at decisional and operative levels, can be essential for companies. In this way, a firm can analyze any specific situation, difficulty or problem in relation to different points of view. This global reading allows knowledge elements, which are useful to reduce complexity and uncertainty, to activate learning mechanisms on critical aspects and action opportunities to be found.
The aim of the study was to identify tools that allow this systemic perspective, the acquisition and structuring of knowledge elements and new knowledge representations to be created in communication contexts, in order to become shared and operative models in "a collective and structured space to face complexity and uncertainty" (Montagna, Norese 2008).
Some observations result from the analysis of experience matured in the OR and DA ambits. First the complexity and uncertainty elements make the use of classical tools (optimization methods, calculator SW tools, etc…) on their own not so comprehensive to face a problem that involves technology, people and organization. Several methodologies and decision support systems have been proposed in literature, but none of them was created (or is normally used) to deal with a complex problem situation from all the useful points of view. The need for a comprehensive reading and for a complete modelling of the problematic situation requires the breaking down of the problematic situation into the relevant aspects and a sequence and synthesis of different technical actions. Second, most of the tools and methodologies have potentialities, but also limits, and can be utilized in different situations, but not in all. Sometimes a tool has to be excluded a priori; sometimes it can be used, but only after the context analysis that defines the applicability conditions. The directions for use differ in relation to the situations; each situation induces a sequence and a synthesis of different technical actions that can be translated into a sequence and a synthesis of different tools. Finally the integration becomes an essential requirement for the operative validity of the intervention because more tools, that are used together, help to guarantee the validity of the data, to define robust models and obtain good results.
The Hybrid-Approach intends to integrate tools that facilitate communication on organisation knowledge, interpretation of the different individual problem definitions and collective problem structuring (tools of the ambit that are usually known as "soft OR/MS") with others that analytically study and simulate the process activities that characterise the productive context. This approach is based on OR tools, as it uses tools, methods, algorithms and software that are useful in the operative activities and as an infrastructure provide the visual and structured language that is the link between operative and decisional situations.
The general framework of the Hybrid Approach (as described in Montagna, Norese 2008) explains the sequence of supporting activities in a decision aiding intervention, in relation to specific complexity elements and to a prevailing imperative for a decisional and/or operational context. This representation

is possible through the indication of a specific problem situation and its main complexities, the imperative need that emerges from the decisional and/or operational context and determines the "contexts of action" and the expected results. The imperative needs are used to define strategic priorities; the contexts of action are recurring sequences of different supporting activities that can be aggregated by a unique objective. Focusing on specific operative, cognitive or also political–organizational finalities, contexts of action call for different support tools from different fields and perspectives. There are four main contexts of action (Identification, Structuring, Development and Control, labelled Id, Str, Sv and Contr, respectively (Norese, Ostanello 1988), that can develop at a Communicative Level, a Technical Level, or a Technical and Communicative Level. The presence/absence of specific contexts of action in the DA process (and also in the application) results in different typological situations (Montagna, Norese 2008).
The first typology identified in the framework is defined as the *Formalization and Choice of known solution,* the second typology is the *Multidimensional Problem solving* where the problem solving is the prevailing imperative and the last typology is *Decision Problem Structuring* as a problem of "multiple visions and interconnected decisions". These typological situations differ in complexity and represent modules of the general framework. More modules are more hybrid approach applications in a DA process and a DA intervention can be described by the sequence of different modules. The feedback is naturally included in the general schema and the sequence of the contexts of action and their activities is often not linear in the different modules because several cycles can be necessary.

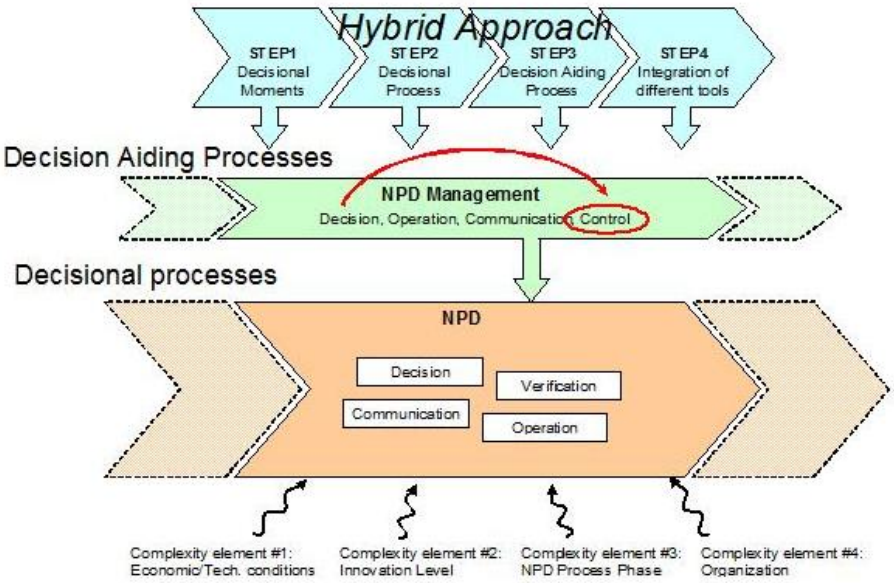

Figure 2. Hybrid approach application steps

In a intervention different decision aiding situations need to be recognized to identify the different modular typologies. The chosen methodology to identify decision aiding situations consists in a rigorous abstraction work to analyze the intervention process and the main process to which the supporting activities are applied. This analysis, using models and tools presented in literature, identifies the decisional moments (STEP1), the decisional processes (STEP2) and decision aiding processes (STEP3) concerning the main process. A close link between decision aiding process typologies and the Hybrid Approach typologies exists and each typology can be associated to each different DA process typology. In this way, the Hybrid Approach application allows the comprehension of the decisional mechanisms and the identification of the supporting activities or

processes, the contexts of action, needed in the intervention. The contexts of actions, focusing on specific finalities, call for different support tools that are available in different ambits. The choice of different appropriate tools to support contexts of action and their integration constitutes the fourth step of the work (STEP4) as shown in figure 2.
By this analytical process, the Hybrid Approach application constitutes the framework for the rigorous integration of tools coming from different perspectives and this integration allows to deal with a complex problem situation from all the useful points of view.

4. The intervention and the Hybrid Approach application in BUSIT

The problem presented to the analyst by the responsible of the engineering department of the BUSIT concerned the analysis of the NPD process of the unit and the identification of an innovative methodology for the management of NPD. In particular the request included the development of a formal control mechanism for the NPD process and a support in order to reach the comprehension of the communication and decisional mechanisms, before choosing the more suitable control mechanism.
The presence of confuse informative elements and uncertainties define the Identification and Structuring contexts of action as the most needed in the first phase of the intervention and in the first hybrid approach application. These contexts of action call for tools for collecting informative elements, reducing uncertainties and structuring the problematic situation.
Structured interviews dealt with the identification of the informative elements. In particular, the identification of the preliminary vision concerning the problem were made in interaction with the problem owner, who provided a brief description of the current NPD process. The BUSIT processes were non-standard (for the oneness of the products, very long NPD, etc…) and flexibility in the NPD is needed. These features had to influence the perspective on the NPD management and the development of the formal control mechanism. The chosen tools had to rightly fit the control needs, the very different kind of projects, the organizational structure and constraints. Also the identification of the NPD environmental information had been performed with an expert internal to the BUSIT organization. He helped the analyst to identify the BUSIT NPD processes and project control methods (applicable in the BUSIT situation) and to reduce the uncertainties on the historical project management routines, the NPD activities and the involved actors.
The structuring context of action was faced with STRAD (the software which supports the Strategic Choice Approach implementation (Friend, 1989)). All the collected informative elements were included in the problem structuring model defining the main focus of the intervention and the control mechanism alternatives were developed by defining all the options for each decision area. The specific requirements for the control mechanism were explored identifying what kind of control mechanism was needed (CM TYP), which and how many tools were considered suitable (TOOL TYP and TOOL NUMB) and which NPD processes should have been considered with priority (NPD PR). The control mechanism in fact, could be extremely detailed, detailed or as a ground plan; MS Excel, MS Project or Design Structure matrices could be used as alternative useful tools and the control mechanism cold be implemented on the more complex NPD processes or on all the NPD processes. The BUSIT uncertainties concerned the NPD activities that were not explicitly defined and known in the company (NPD ACT) and the NPD management activities that were not clearly declared by the management (NPDMNG ACT). Also the activities that should have been considered with priority (ACT PRIOR) for the control mechanism definition represented a technical uncertainty area. The Decision areas, which are in focus, allow the new alternatives to be designed verifying the compatibility of these options in the Schemes and Compatibility windows and the Comparison areas (i.e. time to assess the impact in the NPD management procedures, effort to evaluate the effort in the use, etc.), are used to compare the alternatives. All these aspects are shown in figure 3.
This new model globally proposes all the significant elements that have been acquired; it seems to be sufficiently rich and allows that quantitative and/or qualitative evaluations can be easily elaborated in a dynamic way in relation to structuring context of action. It is a good basis for discussion to facilitate communication between the analyst and decision-maker, the analyst and experts and the decision maker and experts.

The two main dimensions of the problem (Process Modelling, Design of the Control Mechanism) developed simultaneously in the second phase of the intervention. The Structuring and Development contexts of action are present in this second phase where information has to be structured to define a NPD process model and for the development of the control mechanism.
The IDEF methodology and the flowchart diagrams assisted the analysts in analyzing performed activities, needed resources for each activity and criticalities (i.e. duplication of activities, unessential or useless activity cycles or wrong information transfer). These representation tools enhanced the definition of a common language between the BUSIT and the analysts, as well as among all the involved actors, through its simplified graphical devices.

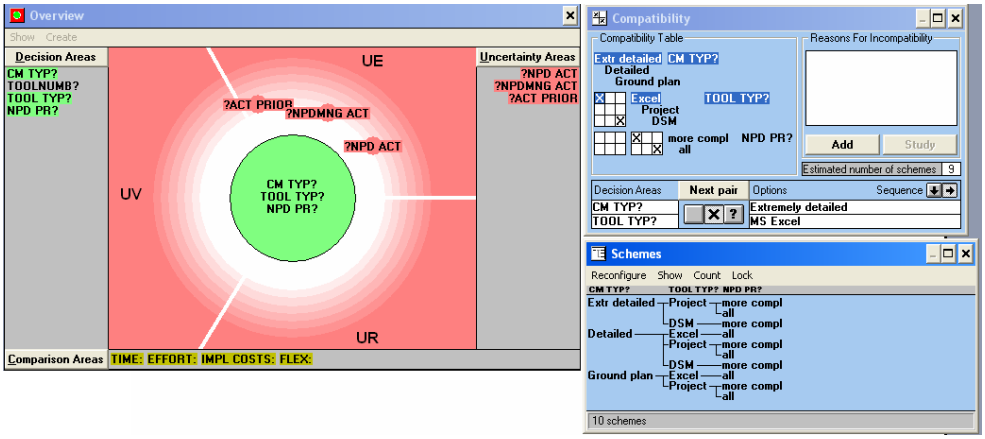

Figure 3. BUSIT problem structuring with STRAD

On the other side, the control mechanism, that had to be valid for the different type of NPD projects and successful in its development and implementation, was designed by MS Project in order to match the identified needs and the data available. The complete project control process and the performance elements (duration, completion, capacity, etc…) to be inserted in the control mechanism were recognized with the main actors of the process (the project controller, project manager and the Engineering Department managers). The implementation of a first solution and a proposal of a intervention methodology for a successful development and implementation of the control mechanism were the results of this second phase. At this aim, the analyst suggested that the vision of the NPD management problem was shared with the NPD involved people and that useful suggestions or data were collected to improve the solution.
The third phase was characterized by the presence of the Identification and Structuring contexts of action for the identification of the weaknesses in the model and the management of new uncertainties pertaining the role of the control mechanism in the organization emerged. The Engineering Department manager could use this new control mechanism to verify the project control made by the Project Controller and some conflicts could emerge. besides, the project control tool had to be shared among people involved in the process and all the engineering different units could use the same tool for the management activities. The access to the control mechanism from multiple users and the usability of the tool by each of them represented a technical focal objective.
The control mechanism model and the relative tools were reviewed in the fourth phase of the intervention to ensure usability and shearing needs. In particular MS Project was excluded while Excel was preferred and some technical solutions to solve the problem of the usability are proposed but not implemented yet.
The presence of different contexts of actions called for different tools case by case, the application of the Hybrid Approach and its typologies allows the description of this intervention as shown in table 1.

Table 1. The description of the intervention in BUSIT with the Hybrid Approach general framework

CONTROL MECHANISM DEVELOPMENT PROCESS	Hyb. Appr. Step1	Hyb. Appr. Step2	Hybrid approach Step3			Hybrid approach Step4			
	DECISIONAL MOMENTS	PD	CONTEXTS OF ACTION	DOMAIN	DAP	HA SITUATION	TOOLS FROM DIFFERENT PERSPECTIVES		
							Project and data management	Engineering Design	RO / DA
FIRST PHASE	Primitive Idea Generation	ENTIRE STRATEGIC DECISIONAL PROCESS (unstructured situation)	Identification	The information elements concerning the NPD process Control mechanism requirements	ACTION STRUCTURING	DECISION PROBLEM STRCTURING	MS Excel		Interviews
			Structuring	Recognition of the control detailed needs as a focus Recognition of the activity priorities					STRAD
			Control	Verification, evaluation and validation of any element that result in the development of the DA process				Flow chart	STRAD
			Development	Generation of the primitive ideas and tool proposals				Flow chart	
			Communication	Increasing in the frequency and effectiveness of unfiltered environmental observations				Flow chart	STRAD
SECOND PHASE	Control Mechanism Development	DEVELOPMENT SELECTION/CHOICE	Structuring	Informative elements to elaborate a global shared and structured vision on the NPD process and its management Definition of the problem dimensions (Process Modelling, Design of the Control Mechanism) Recognition of the performance elements (duration, completion, capacity, etc.) to insert into the control mechanisms Recognition of tool features as the most appropriate for the NPD process	ACTION DEVELOPMENT AND CHOICE	MULTIDIMENSIONAL PROBLEM	MS Access Data base	IDEF0	
			Control	Verification, evaluation and validation of any element that result in the development of the DA process			Gantt charts	IDEF0	
			Development	Control mechanism model NPD process model			Gantt charts	IDEF0	
			Communication	Aid in the creation of global shared and structured vision on the NPD process and its management			Gantt charts	IDEF0	
THIRD PHASE	Changes generation	ENTIRE STRATEGIC DECISIONAL PROCESS (unstructured situation)	Identification	The information elements concerning control mechanism role in the organization and Critical elements present in the control mechanism model	ACTION STRUCTURING	DECISION PROBLEM STRCTURING	Gantt charts	IDEF0	STRAD
			Structuring	Commuting of the critical elements of the control mechanism in usability features			MS Excel datasheets	Flow Chart	STRAD
			Control	Verification, evaluation and validation of any element that result in the development of the DA process			MS Excel datasheets	Flow Chart	STRAD
			Development	Definition of the changes on the control mechanism model			MS Excel datasheets		
			Communication	Aid in the acceptance and use of the control mechanism model by the NPD teams				Flow Chart	
FOURTH PHASE	Control Mechanism Review	DEVELOPMENT SELECTION/CHOICE	Structuring	Definition of the problem dimensions (Ensuring of the usability and shearing, Review of the Control Mechanism)	ACTION DEVELOPMENT AND CHOICE	MULTIDIMENSIONAL PROBLEM		Flow Chart	
			Control	Verification, evaluation and validation of any element that result in the development of the DA process			MS Excel datasheets		
			Development	The review of the control mechanism model			MS Excel datasheets		
			Communication	Increasing in the frequency and effectiveness of the observations on the NPD process and its management			MS Excel datasheets		

The result of the NPD management intervention is shown in figure 4. It is constituted by four steps which involve administrative and technical actors. Each project starts with a quotation phase in order to develop a proposal that must meet the (institutional) client requests and the technical and operative constraints. If the client accepts the proposal, the project control office and the project management settle the work packages needed and each involved cost centre division details the activities and the required resources in respect to the work amount and the time constrains. This scheduling phase is supported by the system engineer and supervised by the engineering department manager. After the project kick-off, the work status is monitored requiring a certified check slip to each employee. These data are submitted to the cost centres and to the project control office which control the work status and elaborate the possible program changes. In this delicate phase, all the changes introduced should be justified and tracked in order to avoid misunderstanding between the management staff and the

operative units and to reduce the consequent time delays. After the achievement of each milestone the total costs and scheduling tasks are accounted and are useful for quoting and scheduling future projects.

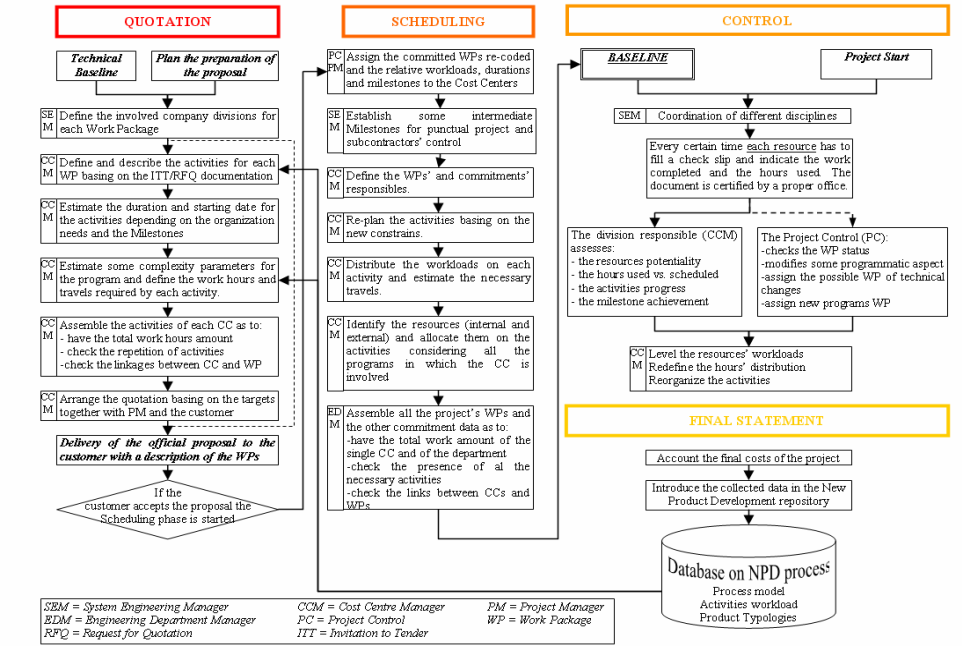

Figure 4. The result of the NPD management intervention

5. Conclusions

Product and process innovation is an actual and hard challenge in each organization. It requires extra attention to be paid to the NPD process and call for new research in the NPD management.

Several elements of complexity and uncertainty make the use of classical tools (optimization methods, calculator SW tools, etc…) on their own not so comprehensive to face a problem that involves people, technology and organization. To identify and choose the right management tools an insightful comprehension of the communication and decisional mechanisms is needed. The integration of different tools, techniques and technologies can be especially useful. A hybrid-approach is the proposal of a new use of tools, which sometimes are old and very simple but always adopt a visual and structured language. This approach integrates in explicit communication spaces more traditional tools with other tools that are more oriented to modelling the whole problem situation and the possible solutions.

A hybrid approach can be applied in different problematic situations that need for diverse technical aids. It can always sustain the technical intervention. Communication becomes the most important activity and the technical action supports communication in the organizational processes. Reasoning about problem context is essential for the choice and correct use of tools and their intelligent integration. The relationships between decisional and operative contexts have to be analysed in relation to different situations of decision support and integrated in the general framework.

This approach has been applied in an Italian automotive firm (Montagna and Norese, 2005), and recently in an Italian firm aeronautic sector (Montagna, 2007). The paper presents the intervention

in a Franco-Italian aerospace company where the characterizing element was the addressing to inter-disciplinary problems with multiple, heterogeneous, distributed systems that are embedded in networks at multiple levels and multiple domains.

References

Adler P. S., "Interdepartmental interdependence and coordination: The case of the design/manufacturing interfaee", Organization Science, Vol.6, No.2, 1995, pp. 147–167.

Brown S. L., Eisenhardt K. M., "Product development: Past research, present findings, and future directions", Academy of Management Review, Vol.20, No.2, 1995, pp. 343–378.

Norese, M.F, Ostanello, A., "Decision Aid Process Typologies and Operational Tools", In: Ricerca Operativa e Intelligenza Artificiale", Proceedings of the AIRO '88 Meeting, Pisa, Italy, 1988, pp. 661-680.

Suh, N. P., "Axiomatic Design. Advances and Applications", Oxford University Press, New York–Oxford, 2001.

Eppinger S. D., "Model-based approaches to managing concurrent engineering", Journal of Engineering Design, Vol.2, No.4, 1991, pp. 283–290.

Tatikonda, M.V., Rosenthal, S.R., "Technology novelty, project complexity, and product development project execution success: a deeper look at task uncertainty in product innovation", IEEE Transactions on Engineering Management, Vol.47, No.1, 2000, pp.74-87.

Galbraith J. R., "Organization Design", Addison-Wesley, Reading, MA, 1977.

Friend, J., "The strategic choice approach", In: J. Rosenhead, ed., "Rational analysis for a problematic world: problem structuring methods for complexity, uncertainty and conflict", Wiley, Chichester, 1989, pp. 121-157.

Marzano G., Norese M.F., Silli E., "Information management and multicriteria methods in a context-sensitive decision aid", Proceeding of IFIP WG 8.3 working conference, Context-Sensitive Decision Support system, Bled, Slovenia,1998.

Chen, J., Reilly, R.R., Lynn, G.S., "The impacts of speed-to-market on new product success: The moderating effects of uncertainty", IEEE Transactions on Engineering Management, Vol.52, No.2, 2005, pp. 199-212.

Henderson, R.M., Clark, K.B., "Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms", Administrative Science Quarterly, Vol.35, No.1, 1990, pp. 9-31.

Montagna, F., "Managing a dispersed process: Decision aiding and knowledge management tools in innovative NPD contexts", PhD thesis, Politecnico di Torino, 2007.

Montagna, F., Norese, M. F., "A Hybrid Approach to Model Design and Development Processes and Evaluate Innovation Opportunities", the International Journal of Manufacturing Technology and Management, Vol.14,No.3-4,2008.

Mintzberg, H., Raisinghani, D., Theoret A., "The structure of the unstructured decision process", Administrative Science Quarterly, Vol.21, No.2, 1976, pp. 246-276.

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