A Hybrid-Approach to Integrate Context Modelling and Decision Support

Abstract

New product design is a crucial process for the firm and always induces innovative and unstructured situations that must be deeply analysed. The firms need tools that allow essential knowledge elements to be acquired and structured and new knowledge representations to be created and proposed in communication contexts, to become shared and operational models. Reasoning about context is essential for the choice and correct use of a tool or the intelligent integration of different tools to support the decision in the process.

The relationships between decisional and operative contexts have been analysed in relation to real processes of new product design and three different situations of decision support are proposed as possible forms of a hybrid approach, which integrates context modelling and decision support.

Keywords: New product development, context analysis and technical approach integration.

Introduction

Uncertainty and difficulty of analysis characterize strategic problems and make orientation and decision making very difficult. A high technology innovation level and complex productive systems are elements that imply difficulties. Elements of complexity exist not only in internal organization processes but also in the relationship with the external environment, the market and any other organizations that might be co-operating on some specific activities.

Organizations must adopt a global reading of these difficulties and the consequent problems, to activate learning "mechanisms" concerning the distinctive and critical aspects, particularly in relation to the innovative processes, such as the design and development of new products.

Over the last decade, the academic community has paid a great deal of attention to product development in manufacturing firms. The diffusion of some concepts, which are considered central for specific methodologies (e.g., Concurrent Engineering, stage-gate product development, Quality Function Deployment, Design-for-X), is now also evident in industry and not only in literature on the product development research area.

In relation to the design and development innovative processes, multiple communities are involved and interact with highly specialized technologies and different knowledge domains. If the organizations are collective (and sometimes virtual) structures that face problematic situations, they need tools that help communication among the involved groups, to create common organizational knowledge and also to improve an exchange of knowledge concerning common problems.

The contexts of product and process innovation and development must be analysed in depth to produce knowledge elements that should be used to reduce complexity and uncertainty and to manage the innovative and unstructured situations. These knowledge elements have to be acquired and structured and new knowledge representations created and proposed in communication contexts, to become shared and operational models and to facilitate decision.

The main elements of complexity that characterize the external and internal contexts in which firms operate, in relation to product and process innovation and development,

are described in the first section of the paper, with the methodological environments that analyse these contexts and propose new perspectives, concepts and tools.
The elements of complexity and uncertainty that are present in the design and development innovative processes make a 'rational' approach not so comprehensive to face a problem that involves people, technology and organization. The paper presents a hybrid-approach, which integrates problem identification and structuring methods in uncertainty management and decision aiding procedures.
This approach is discussed in the second section and put in relation to a framework that distinguishes sequences of technical/procedural and communication activities, which are strictly interrelated and have to be developed in the organization to support the context analysis and modelling and to implement decision aiding procedures[1].
The framework is illustrated in the third section in relation to some different typologies of decision aiding in which the hybrid-approach always facilitates the technical intervention, but in some cases is almost an essential condition to produce valid results.
The role of this approach, its results, the potentialities and its limits are analysed in relation to different problem situations and above all in relation to a recent application that is described through the proposed general framework.

1 New product development context

Each individual company develops its own processes to gain market shares with its own products or services. These processes can change the nature of the organizations and increase the global complexity.
The products can be complex, in technological terms, but also because they include service components. This is the result of a progressive levelling of the products, in terms of features and performances, that moves the competition focus towards services that can be associated to the product, as an intangible part and determinant factor for client satisfaction. The exclusive customer nature of a service imposes choices and specialization, at a firm level, in terms of specific offers of services and focused attention on the requirements of particular customer groups.
Other characteristics, of the product and the industrial process, simultaneously tend to reduce the internal 'connection' of the firms and lead to new forms of co-operation and co-ordination among the organizations.
The adoption of new product architectures and the multi-disciplinary nature of some industrial processes stimulate new organization design and decoupling of the processes, which can become concurrent, autonomous and distributed.
At the same time, this way of working induces a progressive weakening of the boundaries of firms and it is now common to observe firms living in a complex network of horizontal and vertical relationships. These new organizational structures can provide important strategic flexibility because a firm is able to link together the capabilities of many organizations to form product development "resource chains".
The new elements of complexity are due to the presence of different, and sometime distant, participants, with different values and points of view, when multiple communities and different knowledge domains are involved and interact in relation to highly specialized technologies (Brown and Duguid, 2001). As a consequence, the complexity of these contexts has to be analysed and reduced and both the interactions

[1] The terminology 'decision aiding procedures' is used to indicate methods, methodologies and Decision Support Systems of the European School of "Multicriteria aid for decision".

within the single link and the important relationships between the organizations, which are not always evident, have to be understood.
New product architectures and new organizational structures require new conceptual and operational concepts to manage the product knowledge and its architecture (Sanchez, 1996). The knowledge on the product can be explicit and structured (above all documents on the technical characteristics of the product) or tacit. The distinction between tacit and explicit knowledge has sometimes been expressed in terms of knowing-how and knowing-that (Polanyi, 1966) or in terms of embodied knowledge and theoretical knowledge (Brown and Duguid, 2001). Knowing-how (or embodied knowledge) is often the result of an individual learning process and is characteristic of the expert who acts, makes judgments, and so forth without explicitly reflecting on the involved principles or rules. Knowing-that, by contrast, involves consciously accessible knowledge that can be articulated and is characteristic of the person who acquires a skill through explicit instruction or rules. Explicit and tacit knowledge elements have to be brought out to build new technological knowledge and then a strategic value for the firm (Kogut and Zander, 1992, 1996), but this process is difficult to implement within a firm, and much more so in an inter-firm context.
All these problems require new attention to be paid to the design and development of high technology products and call for new research on product development, to update and adapt methods and tools to the new demand that arises from industry (Catalone et al., 2003). The links between product architecture, design management and development activities have been widely studied in literature from the single firm point of view (see Sanchez, 1996), but seldom considered when several enterprises operate together. Some problems concerning design co-ordination and knowledge management and reuse for innovation, have been tackled in literature.
The coordination of product development activities is studied with the explicit assumption that all the aspects that are relevant to product development are coherent or are managed to obtain a state in which the aspects become coherent among themselves. Such technical, managerial and organizational aspects may be individually modelled and related to each other through a common framework (Duffy et al., 1999). Literature on design coordination has also provided a basis to interpret the outcome of empirical research (Cantamessa et al., 1999) and a theoretical contribution for the development of IT systems to support product development activities (Whitfield et al., 2000).
The literature on knowledge management in design and development processes examines how knowledge can be integrated in complex technology and product development settings (Brown and Eisemhardt, 1997) to define possible new product architectures. The literature on knowledge reuse studies how the development of innovative solutions can be facilitated (Majchrzak et al., 2004; Brown and Eisemhardt, 1997). It examines how a firm's current knowledge can make a more effective design and development, but also a more effective strategic management of design and development possible (Nonaka and Takeuchi, 1985). It emphasizes the need for new competences to flexibly coordinate firm networks in the continuous processes of new product creating (Sanchez, 1996).

2 A hybrid-approach

A firm should adopt an integrated perspective that orients attention towards the external evolving environment and also towards the internal context of work and its complexity, both at the decisional and the operative level, to analyse each specific situation in relation to different points of view and to find possible opportunities of action. Tools, which must be perceived as not being external to the organizational

processes and which can facilitate communication and knowledge sharing, could support this global reading and be accepted as a collective and structured 'space' to face complexity and uncertainty.
Reasoning about contexts (both at the decisional and the operative level) is essential for the choice of a consistent approach, the identification and correct use of a 'tool' (general term to indicate several possibilities, i.e. a procedure, a method, a computerized system, a representation model and so on) and the intelligent integration of different tools to support the main actions in the process.
The relationships between decisional and operative contexts have been analysed in relation to real processes of new product design and an approach, which integrates different tools and supports decision and action in different situations, has been applied and tested (Norese, 1996; Francardi and Norese, 1996; Norese et al., 2004; Amata et al., 2005; Guarino and Montagna, 2005).
Several methodologies and decision support systems are 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: to recognize the complexity level and identify the most critical elements, to structure the problem and the information context and reduce complexity and uncertainty, to describe processes and their evolutions, to identify and/or elaborate solution ideas and evaluate them for selection or choice, to plan and control the implementation process. An integration of different compatible tools facilitates a global action; the integrated use of tools from different origins allows a hybrid-approach to be applied to situations that require a sequence and a synthesis of different technical actions. This 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. It integrates these tools in explicit communication spaces and with other tools more oriented to develop and evaluate strategies.
Some problem structuring methods (see, for instance, the most famous that have been proposed in Rosenhead, 1989) support the activities of system analysis and problem identification. They can be usefully used in new product and process development (NPPD) contexts and easily connected to modelling procedures and methods that arise from Operations Research (above all simulation, optimisation and multicriteria decision aiding methods) or Performance and Strategic Management. Complex decisions imply the use of dedicated tools, but the exchange of knowledge concerning common problems among people is fundamental in organizations that face innovative situations. Communication can help to create new organizational knowledge and organizations therefore need tools that help communication among the involved people (the actors of each NPPD context) and activate collective learning "mechanisms" in the organizations.
This hybrid-approach intends to integrate tools that facilitate communication on organization knowledge, interpretation of the different individual problem definitions and collective problem structuring (tools of a context which is usually known as "soft OR/MS – Operations Research/ Management Science") with others that can analytically study and simulate the process activities that characterize the work context and support the decisions of each problematic situation.

3 General Framework

The general framework describes the sequence of activities of a hybrid-approach application, in relation to specific complexity elements and to a prevailing and imperative need for a decisional and/or operational context. Its structure has origin

from the scheme (as it is proposed in De Marco, 1999; in the QPR company web site[2]) that graphically represents the process of a Balanced ScoreCard (BSC) application (see figure 1).

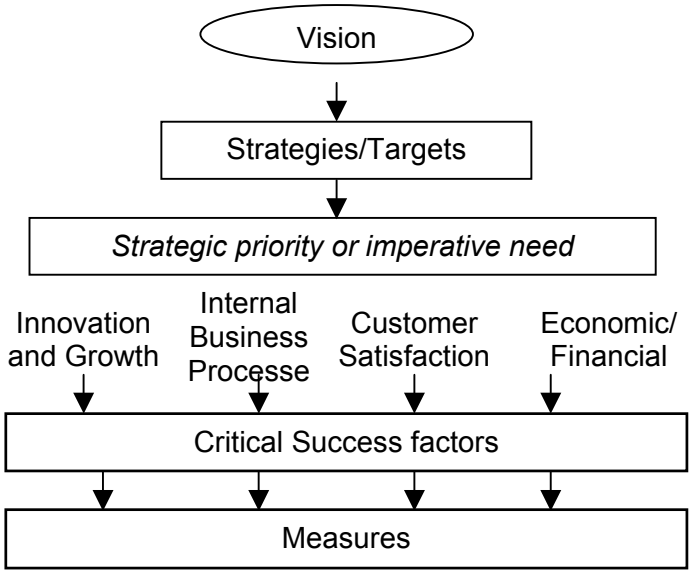

Figure 1: BSC Scheme

BSC is a methodology that facilitates the conceptual passage from a performance measurement system to a system that drives performance, that is a strategic management system (Kaplan and Norton, 1992; 1996). BSC translates vision and strategy into action through several connected activities: clarifying the vision and gaining consensus, communicating and educating, setting goals, linking rewards to performance measures, setting targets, aligning strategic initiatives, allocating resources, establishing milestones, articulating the shared vision, supplying strategic feedback and facilitating strategy review and learning. Multiple perspectives (i.e. organizational learning and growth, internal business processes, customer perspectives, financial measures) support the translation of vision and strategy in relation to a strategic priority or an imperative need. Organizational learning and growth measures are the drivers of the internal business process measures. The measures of these processes are in turn the drivers of the customer perspective measures, while these are the drivers of the financial measures (Norrekit, 1999). Kaplan and Norton assume that if a cause and effect relationship between the measures in the four areas cannot be established, the organization has not implemented a BSC.

A hybrid-approach application can include BSC as a powerful tool (Montagna and Norese, 2005). BSC in fact includes attention to communication and learning, adopts a multidimensional reading of the processes and can be easily integrated with modelling and Operational research methods. The general framework represents a hybrid-approach application through the indication of a specific problem situation and its main complexities (as Vision in the BSC scheme), the imperative need that emerges from the decisional and/or operational context (an arrow indicates that this critical and strategic priority orients the action) and determines sequence of activities and their expected results (the contexts of action). There are four main contexts of action (Identification, Structuring, Development and Control) that can develop at a Communicative Level (CL), Technical Level (TL) or Technical and Communicative Level (T/C L) (see figure 2). These contexts of action have been proposed and

[2] QPR company web site: <http://www.qpr.com>, [04.05.2005].

discussed in literature (see for instance Mintzberg et al., 1976; Norese and Ostanello, 1989)
The feedback is naturally included in the general scheme. The sequence of the activities is often not linear because several cycles can be necessary and a good prevision of the required time for this approach is not so easy. A logical synthesis of the activities that the tools make possible is closely related to the specific context of action and decision. An accepted drawback of a hybrid-approach is that the tools have to be logically and operationally compatible, but in general cannot be transformed in an automatic and computerized system.
A hybrid-approach can be applied in relation to different problem situations that require different supports. It always facilitates the technical intervention. Any integrated application of tools that are oriented towards identifying complexity in the problem situations and knowledge and information elements in the context is useful because it can facilitate communication and modelling of a specific problem in its context. A hybrid-approach reduces uncertainty, facilitates knowledge access and transfer and controls the coherence of all the aspects of a model as it proposes the use of simple tools, that are not perceived as external to the organization, and which can produce validated knowledge and information for the development of Information Systems and the use of Decision Support Systems.
In some cases, this approach is almost an essential condition to produce valid results because the situation is very complicated, at the operative and/or at the decisional level. Communication becomes the most important activity and a technical and procedural action has to support communication. In these cases, several complexity and uncertainty elements can be simultaneously present and the framework reproduces a sequence that includes different activities and integrations of tools that are oriented toward facing different complexities.
Some different typological situations are described in terms of modules of the general framework. These were defined and tested in interventions in specific cases of new product and process development.

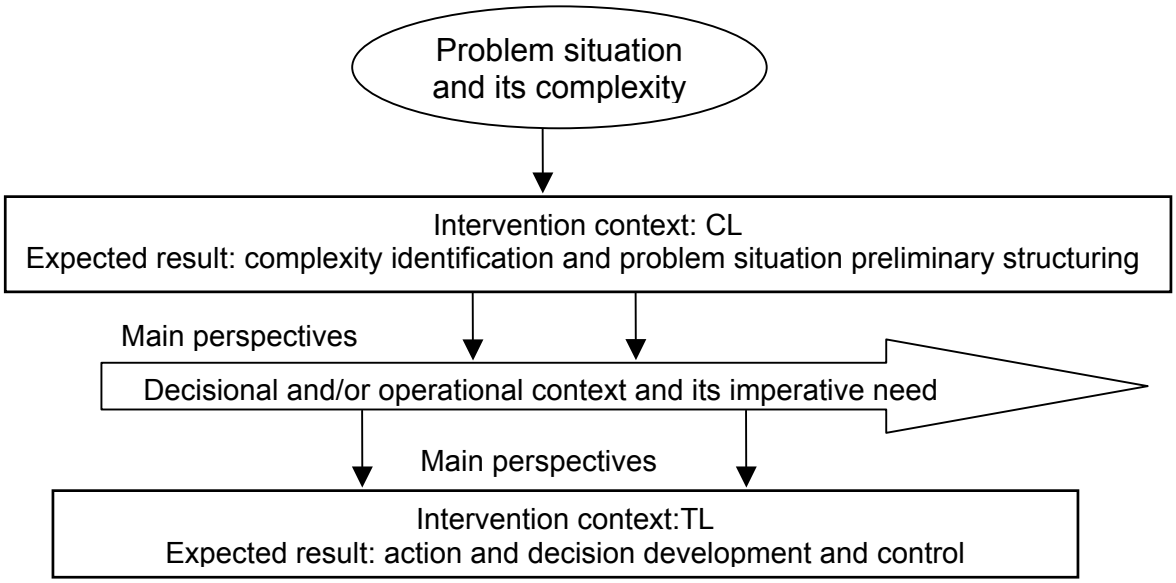

Figure 2: The general framework of a hybrid-approach application

Problem solving

A product can be complex in technological terms. The architecture of a new product and the presence of service components can impose strategic choices in the product and process development and integration between competencies concerning the old

and new aspects of the product and process. Different problems can require a hybrid-approach that faces the requirements of both identifying the nature of the specific problem and analytically developing a solution.
One of these problems can require the organization and integration of all the explicit and tacit knowledge elements concerning the old and new aspects of the product and process. If the complexity and multi-disciplinary nature of some design processes instead stimulate decoupling of the processes, the most critical element is coordination at the system-level of some disciplinary subsystems, which are the essential components of the project. Communication and a positive relationship between different knowledge domains allow the concurrent processes to produce a global and consistent result.
The general framework defines these cases as "multidimensional problems" where "problem solving" is the prevailing necessity in a context that is more operational than decisional (see figure 2+x).
The problem dimensions, in the case of coordination at the system level, are the subsystems, with their languages, objectives and local solutions. The synthesis of these solutions is an essential activity of this problem situation, which can be divided into several dimensions and levels.
The problem dimensions of the knowledge integration case can be:

- acquiring knowledge elements on the product (both tacit and explicit, on the criticality of the old aspects and on the market requirements of new characteristics),
- acquiring knowledge elements on the product development process (potentialities and drawbacks of the old process, potentialities of other organizational processes that can be introduced in this new process, involved functions and competencies,…).

The articulation, in levels of analysis, can be different in the two problem dimensions where communication is always a central activity. The integration of all these elements in a structured synthesis becomes the most technical part of the hybrid-approach.

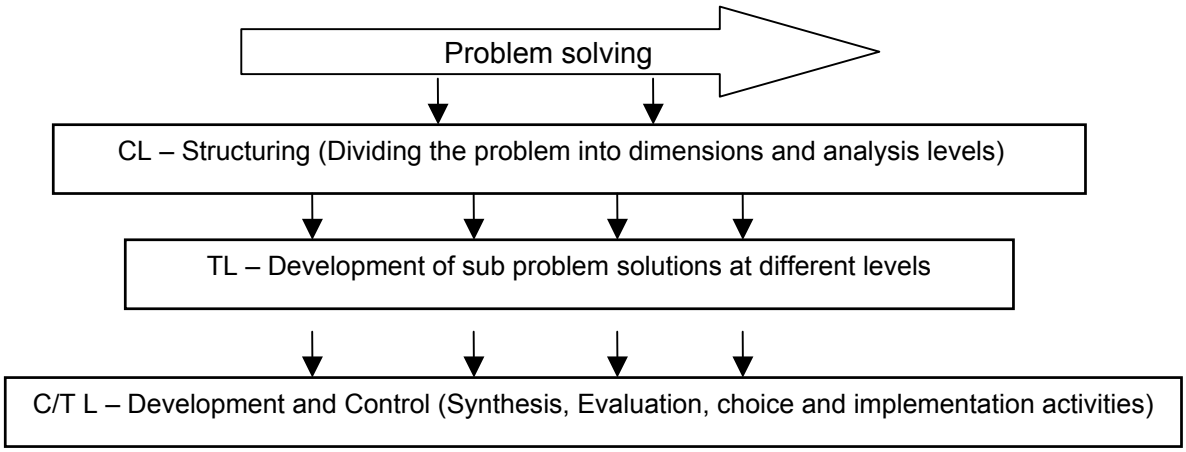

Figure 3: Multidimensional problem

Decision problem structuring

The situation is different when a new product and process development changes the organization design, as described in section 1. The problem becomes one of organizing and integrating all the different technological and organizational aspects to define new forms of co-operation and co-ordination in a firm or in an inter-firm system. Multiple

interrelated decisions characterize these situations, which involve several functions in the firm and multiple communities in the wider system.
The general framework defines this situation as a problem of "multiple visions and interconnect decisions". The context of action is more decisional than operational and the imperative need is "decision problem structuring".
Uncertainties that make the decision difficult are always present in these situations[3], at least in relation to the operation environment of an NPPD. Uncertainties pertaining to the working Environment (UE) can be dealt with by responses of a relatively technical nature (such as surveys, investigations or cost estimations).
Uncertainties pertaining to guiding Values (UV) may be present when the NPPD requires organizational structures as a result of strategic choices. UV calls for a more political response (i.e. an exercise to clarify the objectives or a program of consultations among those who are involved). The kind of uncertainty that pertains to Related decision fields (UR) is present when, in the new inter-firm system, someone who can make significant decisions is not involved in the decision process. UR calls for a response "in the form of exploration of the structural relationships between the decision currently in view and others which appear to be interconnected". 'Decision problem structuring' requires activities of uncertainty analysis and control, development of compatible strategies and selection of the best ones (see figure 4).

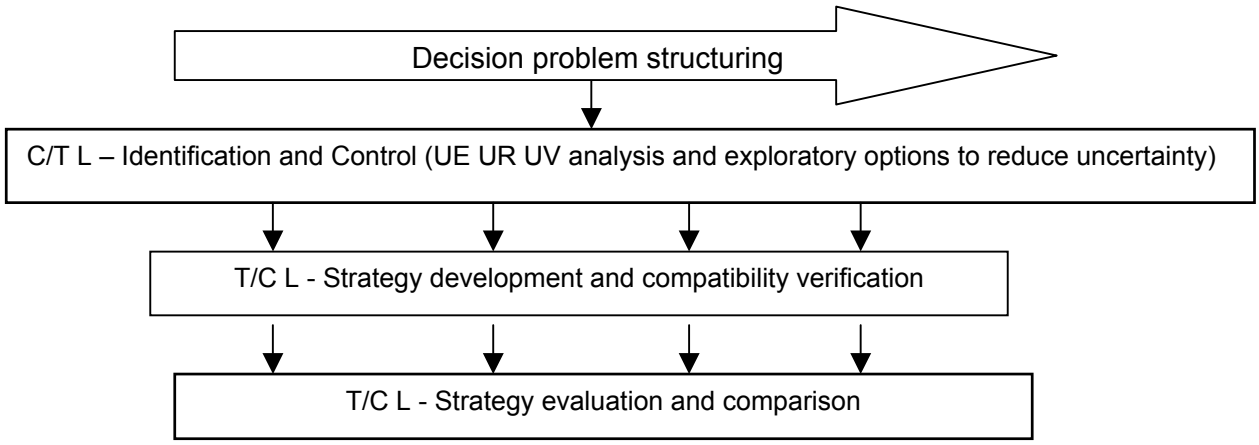

Figure 4: Multiple visions and interconnected decisions

Problem formulation

A different (and perhaps more critical) complexity element is identified when organizational changes do not result from decisions but develop incrementally and in a free and quite natural way. If they are the result of an NPPD, these changes are neither explicitly recognized nor strategically analysed. A sign of this situation may be that the organizational knowledge of the new processes is not available, at least in explicit and structured form. The vision of the global situation is messy (incomplete, confused, not sufficiently structured,...) and has to be formulated or re-formulated in clearer terms.
The general framework defines this situation as a "messy vision" problem and the prevailing necessity is "problem formulation" in the decisional context (see figure 5).

[3] Friend (1989) proposed various sources of uncertainty and ways to face them in his 'Strategic Choice Approach to planning under uncertainty'.

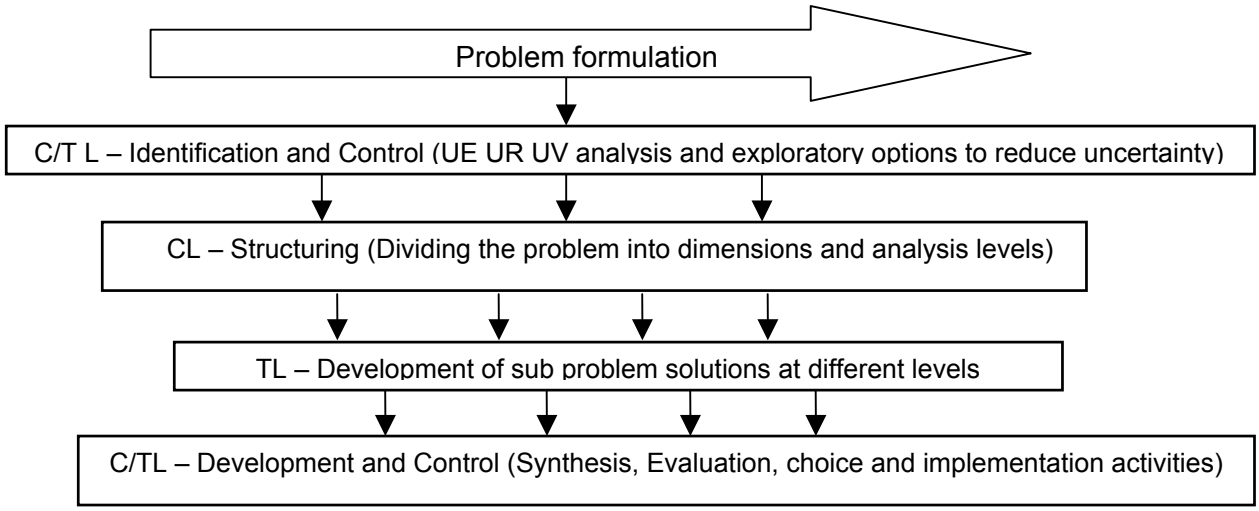

Figure 5: "Messy vision" problem

This module includes and combines action contexts (and specific activities) that are already present in the two previous modules and introduces the more general use of the framework, which represents an intervention process that deals with a complex problem situation from all the useful points of view.

A hybrid-approach was recently implemented in a firm and the initial request ("a formal control mechanism for its product development process") was analyzed and connected to a problem solving situation ("the client's knowledge of the process results to be not so clear and the available information system very poor, then these elements of uncertainty have to be eliminated or at least reduced").

The two main dimensions of the problem developed simultaneously. The actors involved in the operational context were interviewed to obtain a global view of the processes. The IDEF methodology and the IDEF-0 representation software assisted the analysts in identifying what process activities were performed, what resources were needed to perform each activity and what the current system did correctly or wrongly (i.e. duplication of activities, unessential or useless activity cycles or wrong information transfer). IDEF-0 enhanced the definition of a common language between the management and the analysts, as well as among all the involved actors, through its simplified graphical devices.

At the end of this first step, the uncertainties pertaining to the working environment were eliminated and the development of indicator systems became the new imperative need (problem solving). The two dimensions (search in literature and collective reading of the structured organizational processes to produce the explicit declaration of objectives) were explored but did not produce useful results. A new problem-solving situation ("progressive reduction of the uncertainty pertaining to the organization values") was dealt with using a balanced scorecard. Creating a homogeneous and coherent structure of objectives and targets, and of links between each of them and the possible system states, was seen as essential to the aim of a careful definition of the indicators.

The BSC methodology was used as a communication space to reduce uncertainty. When this second kind of uncertainty was sufficiently reduced, a BSC application developed a structure (which included objectives, all the processes and the indicators that are now monitored) that was clearly understood, accepted and shared.

This application of a hybrid-approach is synthesized in figure 6 where the original request is connected to a 'messy vision' situation and to a problem formulation (and reformulation) prevailing necessity. The activities of Identification and Control of the emergent uncertainties became a sequence of two problem-solving modules.

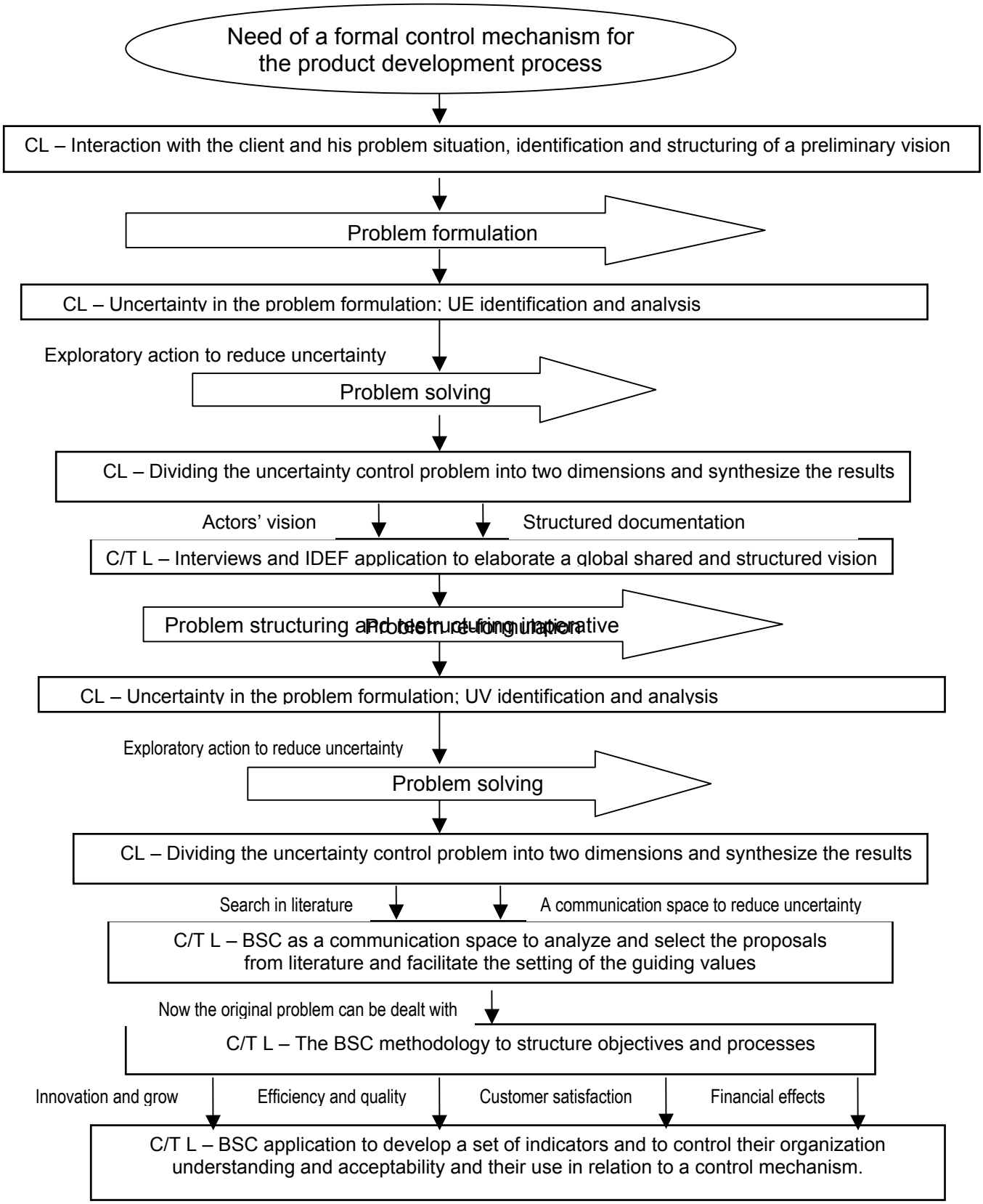

Figure 6: A hybrid-approach application

4 Conclusions

Product and process innovation is now an actual and hard challenge in each organization. Several elements of complexity and uncertainty make a 'rational' approach not so comprehensive to face a problem that involves people, technology and organization. The integration of different tools, techniques and technologies is especially useful when innovation implies a good knowledge of the whole system and of its decision and operative contexts.
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 these tools in explicit communication spaces and with other tools that are more oriented to modelling the whole problem situation and all the involved contexts of knowledge concerning the problem and the possible solutions. Reasoning about context is essential for the choice and correct use of a tool or the intelligent integration of different tools to support the decision in the process.
A hybrid-approach reduces uncertainty, facilitates knowledge access and transfer and controls the coherence of all the aspects of a model because is a proposal of simple tools, which are not perceived as external to the organization, and that can produce validated knowledge and information for the development of Information Systems and Decision Support Systems.
A hybrid-approach application can result as a sequence of activity cycles that reduce the problem complexity by the decomposition of the main aspects and the related analyses or by reformulating the problem until a clear and complete modelling.

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