

# Leveraging Organizational Knowledge To Formulate Manufacturing Strategy

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## Abstract

*This paper describes a web-based system that integrates knowledge management and decision-making features to enable short-term communities of practice develop manufacturing strategy. The system is based on a well-defined model of the problem domain, which builds on organizational activities and resources and their association with the main strategic objectives of the manufacturing function (i.e., cost, flexibility, dependability, speed and quality). Managers involved in the strategy development process may assert their positions towards the issue under consideration, while they may also argue in favor or against positions set by their peers. By stimulating knowledge elicitation, the system captures the informal organizational memory and rationale, and builds a well-structured knowledge graph. In addition, exploiting reasoning mechanisms triggered each time a user inserts a new piece of knowledge in the graph, the system is able to recommend a solution at each dialogue instance. The overall framework proposed in this paper can be used for distributed, asynchronous collaboration for strategy formulation, allowing users to surpass the requirements of being in the same place and working at the same time.*

## Keywords

Knowledge Management, Decision Support Systems, Manufacturing Strategy

## 1. Introduction

The development of manufacturing strategy within an organization is usually a complicated and ill-structured task undertaken by a group of managers representing diverse functions. As such, the

associated issues may be better addressed through argumentative discourse and collaboration among the individuals involved, the aim being to accommodate different views through a process of considering alternative (and possibly competing or even conflicting) problem interpretations, interests, objectives, priorities and constraints. Maximum exploitation and enhancement of the flow of the underlying organizational knowledge are two ubiquitous requirements. Such knowledge resides in an evolving set of assets including the employees, structure, culture and processes of the organization (van der Bent, Paauwe & Williams 1999). Of these, employee knowledge, and particularly tacit knowledge, is essential and has to be fully exploited (Nonaka 1994).

During a decision making process in the above context, managers have to consider a set of alternatives together with their expected impacts for the organization. Moreover, in a knowledge-based decision-making view (Holsapple & Whinston 1988), they have to consider a decision as a piece of descriptive or procedural knowledge indicating the nature of an action commitment. In doing so, the decision making process is able to produce new knowledge, such as evidence justifying or challenging an alternative or practices to be followed or avoided after the evaluation of a decision. In that sense, decision-making and knowledge creation processes are interdependent (Bolloju, Khalifa & Turban 2002).

Executives involved in the strategy-making process adopt and suggest courses of action based on their own background and company position, which fulfill specific goals at specific levels. In practice, opinions about the relevance or the value of a particular strategy differ and are subject to argumentation (Karacapilidis & Papadias 2001). Moreover, strategists working in groups confront the existence of insufficient or overflow information. In other words, for some parts of the problem, relevant to decision making information may be missing, whereas for others, the time needed for the retrieval and comprehension of the existing volume of information is prohibitive. Furthermore, codified knowledge is not always sufficient for making a decision; value judgments, depending on the role and the goals of each manager, are critical.

In practice, what is mostly needed in such a setting is the establishment of common terms of reference as far as the representation of the problem, the assessment of the current situation and the objectives to be attained are concerned. In other words, it is necessary to create a shared mental model on which the alternative knowledge items and/or sources can be attached. In addition to providing a common basis for dialoguing, such a model should provide the means for capturing the managers' rationale during the development of a manufacturing strategy. However, the development of a shared model-based context for articulating and combining knowledge from different sources implies an inherent trade-off, which must be carefully balanced. On the one hand, although too generic models are suitable for situations where creativity is the main objective, in general, they show an inability to provide a consistent integrative framework of diverse views and resolve the issue under consideration. On the other hand, too specific models are usually biased towards certain views leading to the (partial) exclusion or undermining of other views and knowledge sources (Gamble & Blackwell 2001).

By taking into account the above issues, this paper presents a web-based system for collaborative development of manufacturing strategy. In addition to providing a platform for brainstorming, it offers a structured language for conversation and a decision evaluation mechanism that is based on a widely accepted theory of manufacturing competitive advantage, namely the resource-based view of the firm. The language used is firm-wide, thus decision makers from all functions within an organization can participate in the discussion. In our system, participants raise issues and then assert,

support and challenge positions by evaluating the contribution, strength and effectiveness of the related organizational activities and resources, on the basis of their personal knowledge and beliefs. An objective scoring mechanism is used as a guide for the most acceptable position (for which opinions are converging).

The remainder of this paper is structured as follows: The next section gives an insight into the resource-based view of manufacturing strategy, thus dropping hints on the items required for the construction of the proposed knowledge graph. In the sequel, we discuss in detail the proposed system and describe its features through an illustrative example. Finally, the last section concludes the paper by commenting on similar approaches and outlining future work directions.

## 2. The Resource-Based View Of Manufacturing Strategy

In the framework of the resource-based view (RBV) of the firm (Wernerfelt 1984), Hayes and Wheelwright (1984) define manufacturing strategy as consisting of a sequence of decisions that, over time, enables a firm to achieve a manufacturing structure, infrastructure and specific capabilities. In contrast to other approaches to manufacturing strategy, which seek a static fit of the manufacturing function with the overall strategic objectives of the firm and its external environment, this approach views manufacturing strategy as a dynamic process. Decisions on the *structure* (facilities, processes, sourcing) and *infrastructure* (organization, human resources policies, production planning and control systems and performance measurement systems) are not independent in context and time, but are considered as consistent actions towards the development of manufacturing resources and capabilities, whose accumulation plays an active role in the development of the firm's competitive strategy by enabling or disabling new activities, or new configurations of activities (Hayes, Pisano & Upton 1996). Obviously, this approach reserves an active role to the manufacturing function as far as its contribution to the firm's competitive advantage is concerned.

In RBV terms, manufacturing strategy refers to the accumulation of tangible (facilities, processes, etc.) and intangible (knowledge, routines, etc) assets/resources. The combination of a specific set of assets, as well as their accumulation level defines at any instance not only the competitive position of the manufacturing function but also the overall competitive position of the firm. A firm's resources (stocks) determine the range and the economics of the activities (flows) in which it can engage at any point in time (Ghemawat, Collins, Pisano & Rivkin 2001). Therefore, the current resource/asset position of the firm plays an important role on the choice of the future competitive targets/objectives as specific resources augment or limit the decision space of future corporate strategies. A firm that has invested in capacity can easily adopt cost leadership strategies by building more capacity and by being supported by its infrastructural attributes (e.g. production planning and control systems), which have been tuned to large scale operations. The same firm, however, will have a difficulty in adopting a mass-customization strategy after developing structural and infrastructural resources for mass production. In this perspective, complementarities and tradeoffs exist among activities, resources, and activities and resources, and they are dynamic, i.e. they are time dependent. This is a major differentiating point of RBV from the essentially static activity system view (Milgrom & Roberts 1995, Porter 1996), which considers complementarities and tradeoffs (substitutions) only among the activities that a company performs. In this view, the competitive position of a firm is determined by the uniqueness of its activity system configuration, which tries to increase the complementarities among activities while reducing their tradeoffs.

In the RBV, explanation of competitive advantage is through the concepts of competences, commitments and capabilities. The ability of a firm to execute a set of specific activities competitively is called a competence (Mills, Platts, Bourne & Richards 2002). A firm that can manufacture goods at low cost is said to have a low cost production competence. Manufacturing's main objectives (cost, flexibility, dependability, speed, quality) and their associated performance measures at-large, can be directly associated with manufacturing competences. Commitments are lumpy, almost irreversible decisions towards a specific strategic direction (e.g. engaged in major capacity expansion) (Ghemawat *et al.* 2001). Capabilities are different from resources in the sense that they are developed by the firm rather than being taken as given (Teece, Pisano & Shuen 1997). Both commitments and capabilities strengthen the resource base of the firm in a unique and inimitable way.

However, although the RBV offers a better conceptual and explanatory framework for the content and importance of manufacturing strategy, it rather complicates the issue when its practice is concerned. First, as in the majority of cases manufacturing strategy is a mixture of planned and emergent strategies (strategies that emerge as the outcome of the adoption and execution of individual activities in the chaotic discourse of organizational life), it is difficult for decision-makers to check, at any time, the consistency of their decisions with respect to the long term objectives of the manufacturing function. A way to evaluate decisions in the context of specific commitments and strategic paths, already undertaken by the firm, is necessary. Secondly, the RBV "opens" and places the manufacturing strategy process in the boundary between the manufacturing function and other interrelated activities (marketing, R&D, etc.). Its formulation requires the accommodation of different knowledge sources and different views on the same issues of concern. Finally, and most importantly, activities and resources are not independent but are interrelated with time-varying links resulting in dynamic complexity and unpredictability as far as the outcome of the strategy process is concerned. A means to harness this complexity by carefully managing the interconnections is required. The system presented in the following section directly addresses the above requirements.

### 3. System Features

The proposed system can be used for distributed, asynchronous collaboration on the formulation of a firm's manufacturing strategy, allowing the involved individuals to surpass the requirements of being in the same place and working at the same time. Its main objective is to augment the effectiveness of short-term communities through the interactive sharing and integration of knowledge between group members. The structure of the dialogue among the participants is based on an activity-resource-competence model that integrates the activity system view with the resource-based view of the firm (Ghemawat *et al.* 2001, Mills *et al.* 2002). The model formalizes the context of the dialogue but it does not limit participants in the expression of their alternative views. In the model used, generic competences such as cost, dependability, quality etc. are assumed to be the result of resource/capability accumulation. Resources are accumulated by performing specific activities. In turn, resources determine the range and the economies of the activities that can be engaged at any point in time. Complementarities and trade-offs are assumed to exist among activities, resources, as well as among activities and resources.

In the following, we present the system's features and functionalities through an example case concerning discussion related to the issue of building additional capacity. In the instance illustrated in Figure 1, three managers have been participating so far, namely the manufacturing manager, the

marketing manager and the purchasing manager. As shown, our system maps a multi-user decision making process to a knowledge graph with a hierarchical structure. Each entry in such a graph corresponds to a discourse item. Each item is accompanied by an icon (put in front of it), which is associated to its type (this icon also serves for folding/unfolding purposes). The right arrow icon appearing in some entries declares participation of more than one user in the related part of the discussion. Moreover, each entry contains the username of the individual who submitted it and the date of submission.

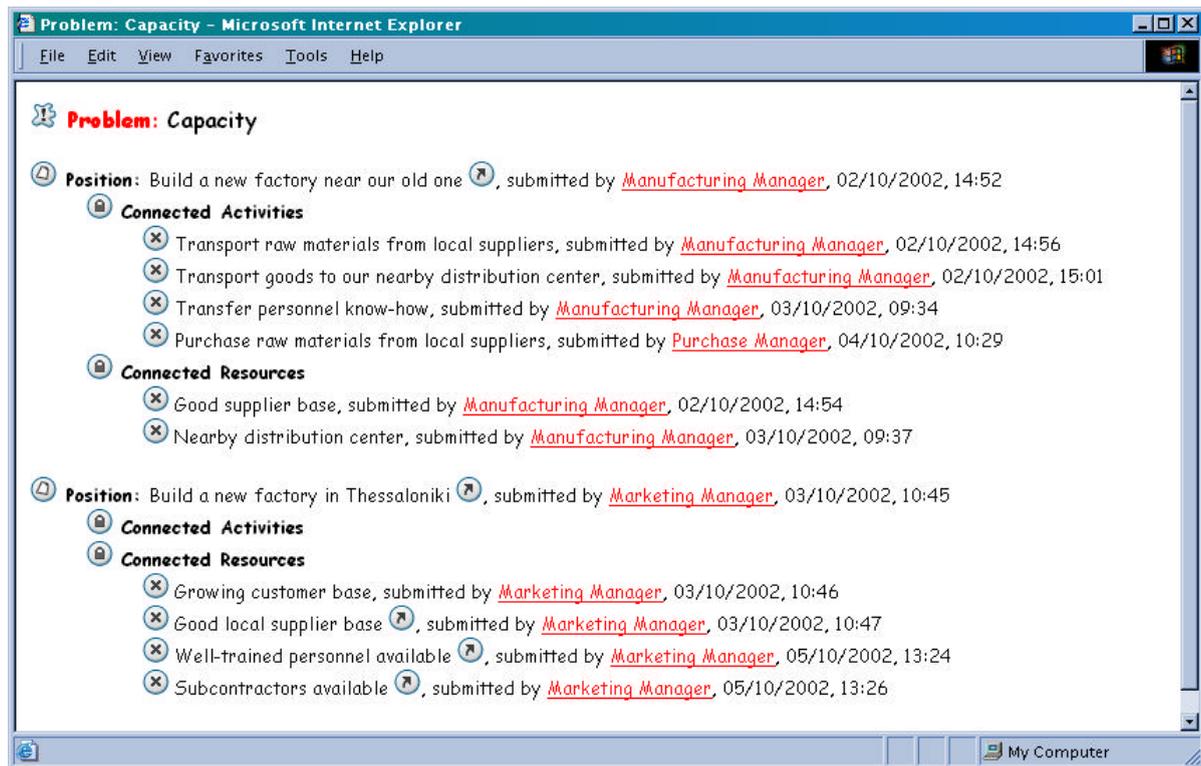


Figure 1. An instance of a knowledge graph.

The basic knowledge items used in the proposed model are problems, positions, activities and resources. Problems correspond to issues to be resolved, opportunities to be seized or goals to be achieved (e.g. "Capacity"). They are brought up by managers and are open to dispute (the root entry of a knowledge graph has always to be a problem). Problems consist of a set of positions that correspond to alternative choices (e.g., "Build a new factory near our old one" and "Build a new factory in Thessaloniki", asserted by the manufacturing manager and the marketing manager, respectively). Positions are associated with activities (e.g. "Transport raw materials from local suppliers", connected to the first position) and resources (e.g. "Growing customer base", connected to the second position). The discussants may evaluate their contribution by arguing in favor or against them.



Figure 2. An instance of an activity.

An instance of the data model used to represent an activity is illustrated in Figure 2. The model conveys information about its *history* in the particular organizational context (values permitted belong to the set {executing, new}), its association to *competences* (i.e., cost, flexibility, dependability, speed and quality) and a qualitative *rate* of its contribution to the position attached (values permitted are in {very\_negative, negative, positive, very\_positive}). Similarly, an instance of the data model used to represent a resource is illustrated in Figure 3. In this case, the model conveys information about a resource's *level* (values permitted are in {non\_existing, developing, sufficient, excess}), its association to competences and a rate of its contribution (as above).

For both activities and resources, competences may be justified by *arguments* speaking in favor or against their contribution to the position they are associated to. For instance, as shown in Figure 3, the *cost* competence is supported by the argument "Cheap local suppliers" while it is challenged by "Expensive local suppliers". Argumentation may be continued in multiple levels, upon the users' will to express their knowledge and beliefs. As shown, "Good knowledge of local market" speaks in favor of "Expensive local suppliers", while two other arguments ("Discount offers can always be found" and "Intense competition among suppliers") speak against it.

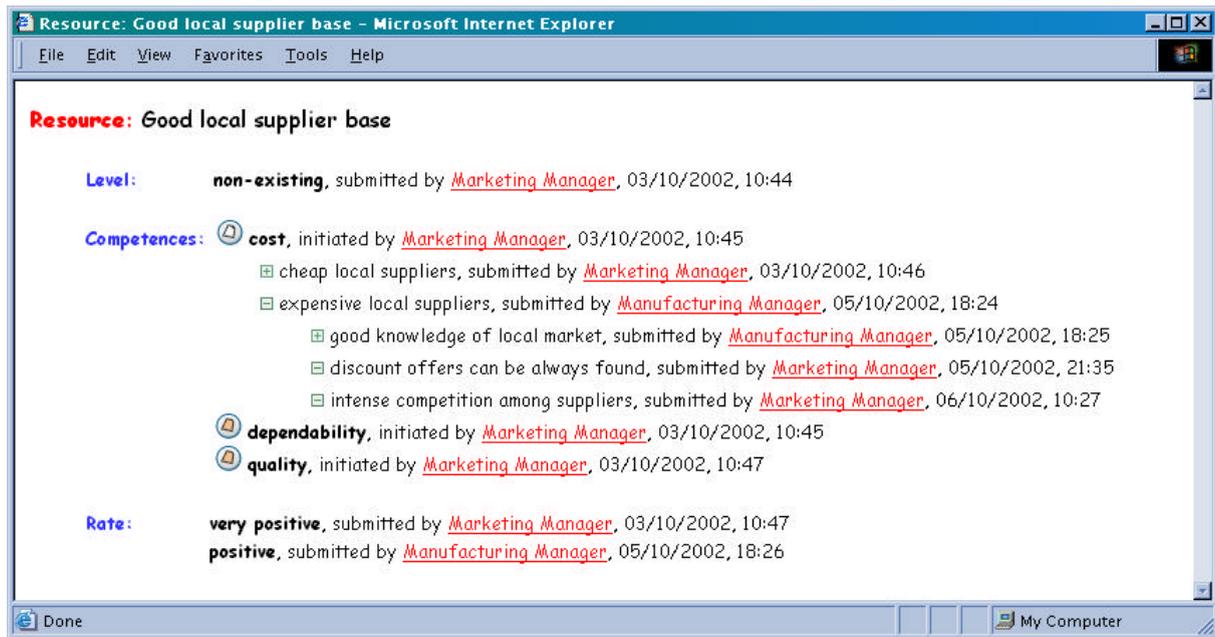


Figure 3. An instance of a resource.

Users assert entries in the knowledge graph through well-designed interfaces. Upon the entry selected each time (by clicking on it), an individual may consider the permitted actions and act accordingly. For instance, when one selects a position entry, he/she may only attach an activity or a resource to it, while having selected an argument related to a competence, he/she may only assert a new argument speaking either in favor or against it. It should be also noted here that the subject (name) of each entry in the graph can be associated with a URL, thus enabling users to link their own discourse items with existing electronic documents that provide additional information or evidence.

The proposed system performs a set of functions to update the discussion status and evaluate the alternative positions. These functions are automatically triggered whenever a new item is added in the knowledge graph and are hidden from the end user. The evaluation mechanism of our approach assigns a score to each position by taking into account the individual scores calculated for each activity and resource, which in turn are calculated through the argumentation already made on their elements. More specifically, the permitted (qualitative) values of a resource's level and an activity's history are associated with numerical values (for a resource's level, the tuple [0.5, 0.7, 0.9, 1] corresponds to [non\_existing, developing, sufficient, excess], while for an activity's history, [0.5, 1] corresponds to [new, executing]) to reflect the related decision risk. Similarly, numerical values are associated with the permitted values of an activity's or resource's rate (the tuple [-3, -1, 1, 3] corresponds to [very\_negative, negative, positive, very\_positive]). In addition, the evaluation mechanism takes into account a ranking of decision makers, which may reflect their expertise in the problem domain and/or their position's impact on the issue under consideration.

As far as competences are concerned, our approach takes into account the existing argumentation and its distribution to the various levels. Each argumentation level is associated with a weight reflecting its importance, the rationale being that an argument at a higher level should have more importance than one appearing at a lower level. These weights are calculated dynamically, upon the

current number of argumentation levels, assuming that the first level is twice more important than the second one, three times more important than the third one, and so on. The weights given to each argumentation level for up to five such levels are shown in Table 1. Taking into account these weights, together with the number and type (*in favor* or *against*) of the arguments asserted, the mechanism assigns a score to each competence of an activity or resource. For instance, for the resource illustrated in Figure 3, the scores assigned to cost, flexibility, dependability, speed and quality are -0.22, 0, 1, 0 and 1, respectively (assuming that participants have equal ranks). It should be noted here that our system allows users to argue on any knowledge item in the graph.

Number of argumentation levels	Level weights				
	Level 1	Level 2	Level 3	Level 4	Level 5
1	1	-	-	-	-
2	0,666667	0,333333	-	-	-
3	0,542328	0,298942	0,158730	-	-
4	0,466125	0,277293	0,160762	0,095820	-
5	0,416463	0,261921	0,160835	0,098462	0,062319

Table 1. Weights of argumentation levels.

In the sequel, the overall score of an activity or a resource is calculated; beyond competences, the total rate of the item and the activity's history or the resource's level are taken into account at this point. Table 2 gathers together the scores given (by the system, according to the existing argumentation) to the activities and resources connected to the first position ("Build a new factory

	cost	flexi- bility	depen- dability	speed	quality
<b>Activities</b>					
Transport raw materials from local suppliers	3	0	3	0	0
Transport goods to our nearby distrib. center	1.5	-1	1	2	1
Transfer personnel know-how	1.1	-1	1	-1.2	2
Purchase raw materials from local suppliers	0	1.3	1.4	2	1
<b>Resources</b>					
Good supplier base	-1	-2	-3	1.7	-2
Nearby distribution center	-1	-1	1	2	1
<b>Total contribution</b>	3.6	-3.7	4.4	6.5	3

Table 2. Scores of activities and resources.

The scores appearing in the last row of Table 2 are the total contribution of activities and resources to each of the base competences of a firm. Positions are evaluated with respect to these values

(according to various aggregation schemata, assuming equal or different weights for competences, performing pair-wise comparisons etc.). It should be noted here that the choice of the quantitative values assigned to all parameters, especially to those involved in the scoring mechanism, may certainly affect the system's final recommendation (total score of a position). The values used for the calculations given in this paper were appropriate for the specific problem domain at the specific level of detail, as the related sensitivity analysis has shown (a detailed presentation of such an analysis is beyond the scope of this paper; rather, we focus on the presentation of our overall approach to solving strategic problems). Depending on the specific problem in hand, different scoring mechanisms, based on alternative algorithms, can be used. In addition, depending on the particular implementation and organizational context, positions can be evaluated with respect to more detailed competences (e.g., supply chain management, use of statistical quality control methods, etc.).

## 4. Discussion and Conclusion

The development of systems that support argumentation and capturing of decision rationale for different types of user groups and application areas has been receiving growing interest in the last years. Such systems address the needs of a user to interpret and reason about knowledge during a discourse. Based on gIBIS hypertext groupware tool (Conklin & Begeman 1987), QUESTMAP (Conklin 1996) captures the key issues and ideas during meetings and attempts to create a shared understanding by placing all messages, documents and reference material for a project on a "whiteboard", where relationships between them are graphically displayed. EUCLID (Smolensky, Fox, King & Lewis 1987) is another system of this category, which provides a graphical representation language for generic argumentation. JANUS (Fischer, McCall & Morch 1989) is based on acts of critiquing existing knowledge in order to foster the understanding of design knowledge. SEPIA (Streitz, Hannemann & Thüring 1989) is a knowledge-based authoring and idea-processing tool for creating and revising hyper-documents that views authoring as a design process. QOC (Questions, Options and Criteria) is another interesting model to represent the rationale of reasoning in a decision making process (Shum, MacLean, Forder & Hammond 1993), in that it provides users the means to represent and integrate rationale of varying degrees of stability, at different stages in a design process. Finally, BELVEDERE (Suthers, Weiner, Connelly & Paolucci 1995), originally designed to support students engaged in critical discussion of science issues, uses a rich graphical language to represent different logical and rhetorical relations within a debate. This category of systems provides a cognitive argumentation environment that stimulates discussion among participants; however, contrary to our approach, it lacks decision making capabilities.

SIBYL (Lee 1990) is another tool for managing group decision rationale, which has also been viewed as an extension of gIBIS; while the latter is mainly a hypertext system whose services focus on the representation of a discourse structure, SIBYL should be rather viewed as a knowledge-based system that provides services for the management of dependency, uncertainty, viewpoints and precedents. It implements DRL (Decision Representation Language) that supports among others goals, alternatives, claims and relations among them. In addition, the tool makes people articulate and become aware of the objectives against which alternatives are evaluated, thus targeting to an explicit representation of goals. However, decision-making in SIBYL is only performed through simple decision matrices, where users evaluate alternatives with respect to the goals specified; arguments in favor or against an alternative must be considered by the users before they submit their evaluation.

Increasing interest also develops in implementing Web-based conferencing systems, such as *AltaVista Forum Center*, *Open Meeting* and *NetForum*, to mention some. Such systems exploit the platform-independent communication framework of the Web, as well as its associated facilities for data representation, transmission and access. They usually provide means for discussion structuring and user administration tools, while the more sophisticated ones allow for sharing of documents, on-line calendars, embedded e-mail and chat tools, etc. Discussion is structured via a variety of links, such as simple *responses* or different *comment types* (e.g., *qualify*, *agree*, *example* in *Open Meeting*) to a previous message. However, the above systems merely provide threaded discussion forums, where messages are linked *passively*; this usually leads to an unsorted collection of vaguely associated comments. As pointed out by the developers of *Open Meeting*, there is a lack of consensus seeking abilities and decision-making methods (Hurwitz & Mallery 1995).

Contrary to the above systems, our approach focuses on aiding decision makers (managers in a community of practice) reach a decision, not only by efficiently structuring the discussion, but also by providing reasoning mechanisms for it. Our primary goal is to develop an *active* system that efficiently captures users' rationale, stimulates knowledge elicitation and argumentation on the issues under consideration, while it constantly considers the whole set of the argumentation items asserted to update the discourse status. In other words, the system not only "captures the informal organizational memory" embodied in such environments (Conklin 1992), but also helps the users during the decision making process *per se* by integrating features based on concepts from well-established areas such as Decision Theory, Non-Monotonic Reasoning, and Truth Maintenance. As comprehensively described in the previous section, the reasoning mechanisms of the system can efficiently handle qualitative data and are automatically triggered each time a user inserts a new item (piece of knowledge) in the discourse graph, in that insertion of a new item may change the status of numerous existing ones and make another position look as more promising. As a last note, it should be noted here that the system proposed in this paper is intended to act as an *assistant* and *advisor*, by facilitating communication and recommending solutions, but leaving the final enforcement of decisions and actions to the users. It is able to capture the tacit knowledge of the individuals involved, which can be appropriately stored and exploited by the organization in the future.

Concluding, we argue that a proper integration of knowledge management, decision-making and argumentation features, based on a well-structured problem model, appears as the most promising solution for a contemporary organization to resolve strategic issues. Further to the full implementation of the proposed framework, our future work directions include the integration of two additional modules supporting simulation and case-based reasoning. The former is envisaged to be called in order to further validate a manager's proposal, thus providing additional evidence about the issues considered at each discussion instance (Adamides 2002). The latter would keep track of previous cases, stored in the system's database, thus increasing the efficiency of the system by enabling users to reuse previous instances of similar discussions as warrants to their arguments in the current discussion (Karacapilidis, Trousse & Papadias 1997).

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