A Model for Collaborative Decision-Making for the Evolution of Virtual Enterprises

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Abstract. Grounded on Project Management and Decision Support Systems foundations, this paper presents a distributed environment to support collaborative discussion and decision-making for managing the evolution phase of a Virtual Enterprise (VE). VE evolution deals with problems during the VE operation and that put its goals on risk. The main rationale of this work is that VE members are autonomous and hence that all the affected partners should discuss about the necessary changes on the current VE's plan in order to generate a feasible new plan. In the presented approach this discussion is guided by a flexible decision protocol and the impact of decisions can be evaluated. Final results of a prototype implementation are discussed in the end.

Keywords: Collaborative discussion, Decentralized Decision-making, Project Management, Change Management, Virtual Enterprises.

1 Introduction

Collaborative Networks (CN) have been considered one of the most prominent business strategies to face global competition. Collaboration between companies offers conditions to reduce expenses, increase capacity, broaden markets and improve themselves with knowledge acquired in business [1]. There are several manifestations of CN. This paper focuses on Virtual Enterprises (VE).

A Virtual Enterprise (VE) can be generally defined as a temporary alliance of autonomous and heterogeneous enterprises that dynamically joint together to cope with a given business opportunity, acting as one single enterprise. A VE dismiss itself after accomplishing its goal [2].

Managing the VE life cycle efficiently is crucial for the business realization, so involving the creation, operation, evolution and the dissolution of a VE. This paper focuses on the VE evolution phase. In general, the VE evolution phase comprises activities related to the management of changes and adaptations in the VE's plan in order to achieve its goals and duties. This comprehends actions like modifications in some technical specification, changes or negotiations in the VE's schedule, replacement of some members, among others [3].

VEs impose, however, respecting a number of requirements in decision making. The most important one is that decisions should be performed in a

collaborative, decentralized, distributed and transparent way, considering that VE members are partners, autonomous, independent and geographically dispersed. Besides that, the fact that each VE is per definition completely different from one to another (in terms of number of partners, their skills, culture, local regulations, specificities determined by given clients, etc.) the solution of some problems is not necessarily deterministic and the usage of previous decisions for equivalent problems is not necessarily useful [3].

Within this wide context, this paper presents very final results of previous and so far ongoing research of the authors, providing a collaborative, flexible and human-centered decision support framework to help VE members in the management of problems that cause changes in the VE operation, considering those mentioned requirements. The underlying research hypothesis is that an environment like that can significantly enhance the agility, quality and trustworthiness in the VE decision-making. It assumes that VE members come from a long-term alliance of VBE (Virtual organization Breeding Environment) type, so having some level of preparedness and sharing some common working principles [4].

This research was developed under an applied, partially exploratory, research-action and qualitative scientific methodological basis. The essential value proposition of this work compared to related works on decision-making for VE is to offer a supporting framework and methodology that systematize, guide and assist VE managers in the discussions about a specific problem within the VE evolution phase towards its resolution.

This paper is organized as follows: Section 1 has presented the general requirements for VE management in the evolution phase. Section 2 discusses the problem related to collaborative decision-making. Section 3 presents the developed framework for managing the VE evolution. Section 4 presents the prototype. Section 5 discusses the results and conclusions of this work.

2 Collaborative Decision Making

Distributed decision-making is not a new research topic. A number of works have been developed along the last decade on this matter, especially in the form of distributed decision support systems [5]. Actually, the work presented in this paper follows the same line but it adds diverse elements and requirements from the VE area.

Developing a comprehensive and flexible environment that can cope with those basic requirements for managing the VE evolution phase is very challenging, both in terms of managerial methods and models, and from the IT point of view. Some authors have approached this problem (including the operation phase) in different ways. Rabelo and Pereira-Klen [6] have introduced a fixed decision protocol to deal with changes in the VE. Hodík and Stach [7] have developed a multi-agent-based decision support system to simulate the impact of decisions in a VE. Negretto *et al*. [8] have created a distributed supervision system to monitor the VE plan. Noran [9] has developed a decision support framework to help managers in the partners' selection in the VE creation. In spite of their values, they are limited in properly coping with two key requirements in the VE evolution: the need for

decentralized decision-making and the consideration of partners' autonomy. They assume that the so-called VE coordinator is the only one who has the rights to access all information and to take / impose related decisions, i.e. a centralized approach. The fact is that there are so many particular details to be considered about all the involved partners that it is even dangerous to leave the decision only up to the VE coordinator, regarding that the ultimate goal is to reach a feasible solution and not just another theoretical VE plan. Partners should discuss about the problem, and the solution should emerge from this respecting their autonomies and current governance model.

In order to cope with this scenario, five basic aspects have to be supported for a comprehensive decision-making environment for the VE evolution [3]: Partners' Discussion, Methodological guidance, Decision Protocols, Performance evaluation, ICT Infrastructure. Actually there are several works that handles these issues but in an isolated way. None of the works analyzed in the literature presented a comprehensive decision model and environment that cope with those requirements in an integrated way and that are devoted to the VE evolution phase, which is the case of the this presented work.

3 Distributed Decision Support Framework

In order to cope with the requirements previously mentioned and to transform them into more concrete artifacts and integrated model, a framework has been conceived. It considers such requirements, transform and groups them into four pillars: *Human, Organizational, Knowledge* and *Technological*. The rationale is to enable (empowered) *people* to discuss and to decide about a problem related to a given *organizational* process, applying a set of *organizational* procedures and methods, using information and *knowledge* available in the VBE's data repositories, all this supported by ICT (*technological*) [3]. The *Human* pillar represents VE companies' managers who use their tacit knowledge and collaborative attitude to help solving the problem come from the VE operation. The *Organizational* pillar comprises intra and inter-enterprises processes, ontologies, working methods, techniques and procedures that should be involved in the distributed and collaborative decision-making process. The *Knowledge* pillar comprises explicit information and knowledge available in the VBE's data repositories. The *Technological* pillar refers to all kind of ICT tools, platforms and security artifacts available that help managers accessing organizational methods.

Those pillars are 'operated' through three concrete elements: the *Decision Protocol,* the *Distributed and Collaborative Decision Support environment,* and the *ICT Toolbox*. They all form the *Distributed Collaborative Decision Support System for the Management of VE Evolution (DDSS-VE)*. Based on the classification proposed by Turban and Aronson [10], the DDSS-VE is classified as a negotiation-based, decentralized, partially hierarchical, semi-structured, multi-participant and team-based system. Figure 1 presents the framework's architecture, also illustrating the relation of these elements with those pillars.

VE operation services & systems represent the activities responsible for monitoring and detecting problems in the current VE's plan. Once a problem is

detected, the control flow is passed to the DDSS-VE in order to manage the problem resolution. There are three main modules in the DDSS-VE architecture. The *Decision Protocol* (Figure 2) is responsible for guiding and coordinating the discussions among partners, also considering the set of (configured) particularities of the VE, depending on each case offering the required flexibility and adaptability. The *Discussion Environment* is responsible for supporting discussions among VE partners (VE Coordinator, the VE members and, optionally, helped by an invited expert). It is composed of an instant message module (a *Chat*), a forum module and a file exchange module, where partners can discuss, argument and exchange information during the problem resolution. The *Tool Box* contains a set of tools and software services that help partners in the discussions and evaluations. It is composed of performance monitoring and evaluation tools and other supporting services. ICT infrastructure acts as the 'bus' that integrates all these modules, tools and services as well as that grants access to the VBE database.

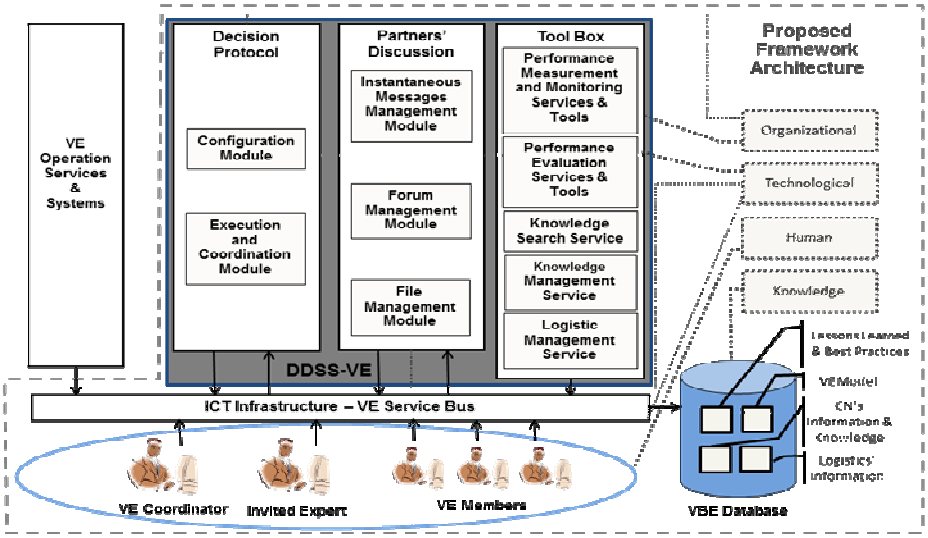

Fig. 1. Framework Architecture

The decision protocol reflects the vision that sees a VE as a *project*, regarding that a project consists of a temporary effort to create a product or a unique service [11]. As such, managers can have a support from project management reference models.

A number of project reference models were deeply evaluated and it was realized that most of them are not adequate at all to cope with the intrinsic dynamics of VEs, where changes and uniqueness are a routine and not an exception, besides the fact that VEs are often short-term projects. ECM (*Engineering Change Management*) [12] was the one considered as the most adequate model, defining the phases of identification of a need of change, the proposal of a change, its planning and its effective final implementation.

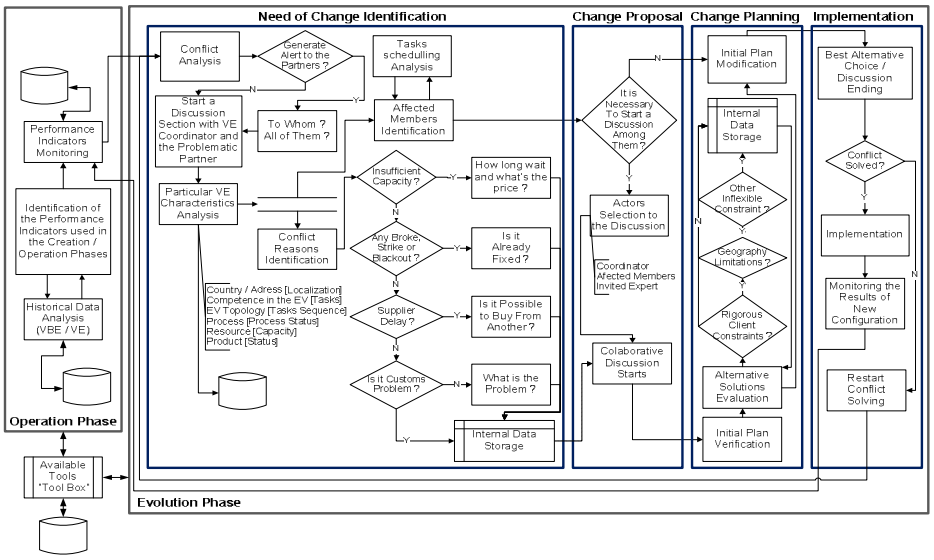

Fig. 2. Basis Protocol for the VE Evolution Management

4 Prototype Implementation

Partners Discussion Environment supports functionalities for argumentation, which were adapted from HERMES system [13]. Yet, it helps partners in finding consensus on topics of discussion (essentially via comparing alternatives to solve problems, checking the impact of proposed solutions at each member, and voting), whose functionalities were adapted from DELPHI method [14]. In general, these adaptations had the aim of supporting partners' autonomy and transparency as well as of providing a more structured way of deciding (via the decision protocol).

The decision protocol helps managers to follow general actions (according the ECM model) at the right moment in the decision making process.

The Toolbox was populated with a tool for capacity planning, which uses dashboards to support performance evaluation. The protocol was modeled in BPMN / BPM environment and its 'decision blocks' (based on ECM) were implemented as *web services*. The whole decision support environment was implemented in a web portal, on top of *Liferay* web application server (www.liferay.com).

4.1 Decision Protocol

Once started the decision-making environment (i.e. once a problem is detected at VE operation phase), the decision protocol appears to each invited participant as a sequence of instructions to be done. These instruction are general steps (from ECM) to guide a more or less free discussion about a problem among the affected VE members. The protocol can be customized for particular cases when a VE is created or can be generally instantiated for the whole VBE, i.e. valid for all VEs.

4.2 Partners' Discussion

Considering that the decision protocol has already passed through the phase "Need of Change Identification" (see Figure 2), figure 3 generally illustrates how the discussion would proceed when trying to solve a conflict from the protocol's phase "Change Proposal" on. In this example, four partners from different countries would be involved: the VE Coordinator (*Mr. Ricardo*) has concluded that it is necessary to start a discussion with two members (*Mr. Marcus* and *Mr. Rui*) due to a problem detected in the specification of the first allotment related to the development of a new helmet style for racing. After starting the collaborative discussion, the protocol enters in the "Changing Planning" phase of the protocol (Figure 2) where different scenarios are evaluated using tools from the toolbox. "Changing Planning" phase ends when the most suitable alternative is chosen in the "Implementation" phase, where the new VE plan is settled and then the VE goes back to the Operation phase.

Fig. 3. Some snapshots of the Partner's Discussion Environment

4.3 Evaluation Tool for Decision Making

In order to offer a tool for previous evaluation of the decision impact using performance evaluation methods, a specific module was developed. The performance indicators were mostly based on the SCOR model [15]. This tool uses different spreadsheets, containing dashboards that offer the possibility to see each partner's competence, production scheduling, available resources, amount of resources, etc., to

consider each partner's task schedule to calculate scenarios for solving the problem under discussion within the DDSS-VE. Figure 4 shows the developed *dashboard*.

For the decision model evaluation and considering the exploratory nature of this research, the system was tested within a controlled environment (in a lab-scale), where some near-real problems were introduced related to some hypothetical VEs using reference information models. Discussions were then simulated in an asynchronous way, with a number of invited users distributed over a set of computers in a local network. The prototype and protocol were executed properly and users could realize the more agility the whole framework provided. Besides that, the system and model were carefully presented to a group of experts in the area, both from academia and companies. After this, an evaluation questionnaire was distributed to them. In general, they all agreed that the proposal has the potential to provide more transparency, quality, agility and confidence in decision-making in a VE scenario.

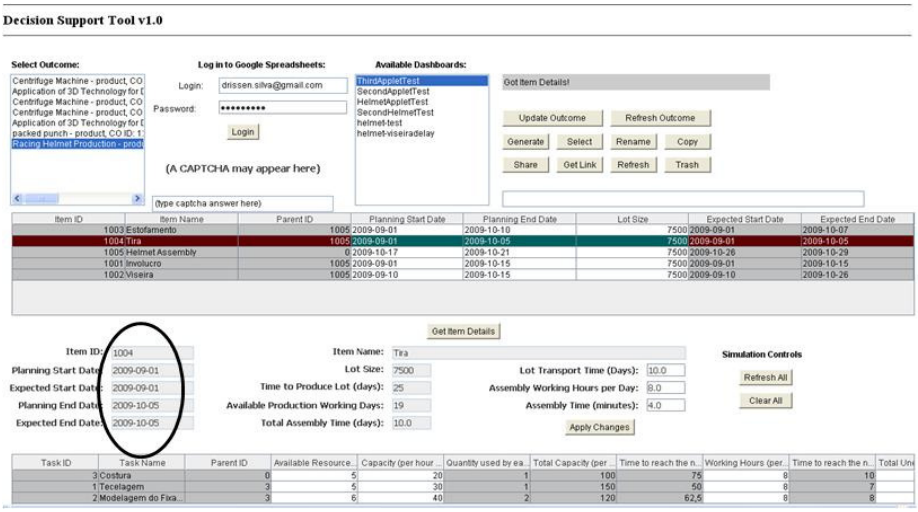

Fig. 4. Evaluation Scenarios Tool using Dashboards for Tasks Rescheduling

5 Conclusions

This paper has presented final results of a research on an integrated model to support collaborative decision-making among VE members for solving problems during the VE evolution phase. The model combines a decision protocol and a distributed and collaborative decision support framework and system. It has been designed to cope with VE requirements, in particular in what members' autonomy and decision transparency is concerned, including some governance and impact analysis.

Discussions are driven by a decision protocol and it is semi-automated by a system. This means that managers' experience and knowledge are preserved in order to reach a feasible solution for the given problem while their macro actions are guided by a protocol that help them to keep focused on the main issues about the problem, having the ECM project management model as the basis for.

The results have showed that supporting partners' autonomy, Internet-based decentralized decision-making, voting and transparency have effectively worked out in a controlled environment. During the discussions, selected partners could have access to the problem, could freely exchange opinions about how to solve it, and could express their preferences via voting. This guaranteed that the solution emerged from the collaboration and trust among partners. The decision protocol drove participants to take actions at the right moment.

Considering the limitations and assumptions applied to this research, it was possible to conclude that a framework like that has the potential to enhance: the agility in decision-making (discussions tends to flow more straight-forwarded as they are guided by a protocol that is based on project management models); the quality in the decisions (as information is obtained on-line and partners can check the impact of possible solutions at their companies); and that partners were more confident in sharing information about problems as long as the environment preserved their autonomy and they could expose their opinions and further voting.

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