A Workflow Model for Designing and Managing Distributed Business Process in Virtual Enterprises

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Abstract

This paper introduces a research activity undertaken to identify the main strategies for enabling an easy and efficient integration among dispersed, heterogeneous workflow systems in virtual enterprises. It starts from the definition of the main features characterizing a virtual enterprise and from the main approaches to workflow designing. The main results are a taxonomy of the desirable characteristics of a workflow management system for virtual enterprises and an assessment of the workflowability of the virtual process.

1. Introduction

A virtual enterprise is “a temporary network of independent companies – suppliers, customers, even rivals – linked by information technology to share skills, cost, and access to one another’s markets. It will neither have a central office nor organization chart. It will have no hierarchy, no vertical integration. Instead proponents say this new, evolving corporate model will be fluid and flexible – a group of collaborators that quickly unite to exploit a specific opportunity. Once the opportunity is met, the venture will, more often than not, disband” [3].

New competitive environments are forcing enterprises to cooperate in innovative and efficient ways. The virtual enterprise paradigm, though appearing potentially very powerful, is hampered by the difficulty in coordinating and letting autonomous organizations working as a single one.

The “planning” and “set up” phases of the virtual enterprise are very de-structured tasks, so it is quite difficult to formulate general rules and indicate a development path. Nevertheless, it is possible to identify a framework in which some entities perform a suitable set of activities. Main operative problems are related to the need for coordination among both members and processes [12] and can be summarized in terms of development of integration methods and management of the distributed business process.

The virtual enterprise is based upon an integrated process (virtual process) composed by a nested set of private core processes, i.e. the resources, skills, and competencies made available by participant firms. Workflow technologies are the main enablers for achieving an efficient integration, monitoring and execution of the entire virtual process.

The aim of this paper is to analyze the workflowability of a virtual process considering the typical characteristics of a virtual enterprise. In addition, we identify the special features of a workflow system seen as a tool for designing and managing distributed business processes.

2. Virtual Enterprises

A list of features characterizing a virtual enterprise can be extracted from literature [5][6][13]:

- **Market-driven cooperation**: the network is set-up to exploit a specific business opportunity.
- **Complementarity**: each partner excels in particular sub-processes and/or has a critical knowledge about the process, the product or the market; in particular, mutual interdependencies among members have to be identified and managed to create a unique combination of resources, skills and knowledge.
- **Dynamic participation**: organizations can connect into the network and disconnect from it in a dynamic way.
- **Legal and economic independence of participating partners**: there are no “focal” members, partners are cooperating on a voluntary basis.
- **Processes/resources sharing**: blurring of single enterprise’s boundaries, partners work together, integrating processes and sharing resources.
- **Time limitation**: the virtual organization is aimed to achieve short/medium terms business opportunities;
- **Transparency**: partners agree in sharing all necessary information, while protecting their own
private core information and knowledge assets from being accessed by others.

- **Polymorphism**: there is no single organizational structure for all virtual enterprises; rather, the organizational structure depends on the business to be exploited and on the characteristics of the partners.
- **Automation**: intense adoption of ICT; cooperation among the partners is possible only by a tight information systems integration.

3. Virtual Processes and the Exception Handling Methods

The business process enacted by a virtual enterprise is hereafter defined as the “virtual” process. The virtual process is not an easy chain of sub-processes supplied by member organizations: sub-processes are not sequentially integrated, instead, they are mixed and interconnected to take full advantage of all the inter-relationships existing among them [10]. Hence, this global process will be likely to become very complex, regulated by precise equilibriums and by powerful feedback systems.

3.1. The development of the virtual process

The virtual process is initially designed considering the global requirements derived from the product/service specifications and from the performance constraints. After this initial phase, an architectural analysis to decompose the problem and to implement process items in increasingly greater detail will follow (top-down approach). The refinement of the top-down process schema will stop at the level of detail in which it becomes necessary to explain how the virtual enterprise combines its resources in the process. The process modeled in such way is naturally effective, since it directly pertains to the market needs; however, its efficiency cannot be assessed in any way since it is not yet clear what resources the process will use and how it will use them. In addition, there is no explanation of how responsibilities and authorities on the process will be shared and distributed among partners.

The development of a standard workflow model to be used in each end every virtual enterprise is usually difficult, since the polymorphism and the tight linkages with market needs are forcing the development of ad-hoc process architectures. This problem could be lessened by adopting a mixed (top-down and bottom-up) workflow development process, which may be easily implemented by users. Our proposal allows to start with a general top-down schema (employing workflow templates) based on the type of process imposed by market requirements and to refine it by means of a bottom up approach employing a PCP library [15].

The building blocks of the virtual process (which are considered like normal tasks) are the sub-processes supplied by member enterprises (private core processes). A private core process (PCP) is the maximum level of detail allowed by an enterprise on its own supplied processes; beyond this level, the private process is seen as a “black box” neither visible nor accessible by external actors. Every member provides the virtual enterprise with one or more PCPs. The entity designing the virtual process has to, taking into account the top-down workflow schema, select necessary PCPs and integrate them in accordance with many efficiency, effectiveness, flexibility and risk control criteria. This schema is then developed by means of a bottom-up approach. A virtual process schema to integrate, manage, and synchronize selected PCP is achieved by combining and fine-tuning the top-down schema with the bottom-up one.

The PCPs integrated in the virtual process may interact in three ways (not mutually exclusive):

1. **PCP Synchronization**: mutual visibility of events allowing the fulfillment of specific pre-conditions triggering the activation of other tasks. After one PCP is completed, another one inherits the processing and its activities. This is the most basic connection model.

2. **Resource Exchange**: the results of a PCP (information, materials, knowledge) become the input of other PCPs. One PCP has part of its processing done by another PCP. As an activity of PCP1 creates PCP2 and has it initiated, then goes into a wait state, with the activity resuming after PCP2 is completed.

3. **Cooperation and sharing**: a virtual PCP is designed as an aggregation of atomic PCPs tightly interacting and cooperating to achieve the output. Two PCPs that are proceeding independently become synchronized at some point and exchange information (or resources in general), and then continue independently. When an activity reaches the synchronization points, it waits for the other to arrive there, and then they exchange resources.

Every PCP is characterized (and known by the virtual enterprise members) by the following set of attributes:

- **Goal**: synthetic formalization of the PCP objective.
- **Output**: description of results (products and/or services) achievable by the PCP.
- **Resources**: human, technological, information, and other resources necessary to perform the assigned PCP.
- **Conditions**: definition of pre-conditions for the activation and events that have to occur to make the PCP start. Each pre-condition must define time schedule, communication methods and ways in which the trigger event would appear.
3.2. Exception handling

Because of the low predictability of the virtual process and the dynamic attitude of the cooperation, it is likely that the process could not be enacted as it was planned. In such a situation, an exception arises. An exception is an internal or external event (which is improbable, not desirable and/or not foreseeable in terms of time manifestation) that, once it occurs, triggers relevant effects on the flow of tasks of the workflow. Usually, traditional WFMS have rules and procedures aimed to run-time handle exceptions [4].

Even if the virtual process is usually difficult to predict, it is possible to design a master flow of tasks and to identify alternative paths triggered by high probable exceptions. As for the exception characterized by low probability, recovery actions are designed based on the effects on the product/process. Indeed, since it is neither possible nor desirable to foresee all the events potentially affecting the virtual process, it is impossible to assign a specific recovery action to any possible exceptional event. Hence, the exceptions not very likely to happen would not be classified in terms of causes but in terms of classes of effects. Responsibilities and authorities for the recovery actions are then assigned to any class of exceptions. Finally, when a high improbable exception event triggers large effects on the workflow, it might be necessary to re-negotiate and re-engineer the virtual process. The following sections will analyze applicability of workflow management systems in a distributed, dynamic environment.

4. Workflows and the Virtual Process

Workflow systems appear particularly useful in managing the virtual process. However, the application of WFMSs to manage virtual processes is in general more difficult than in traditional enterprises [14]. Member organizations should be able to join the virtual enterprise and to start a very tight cooperation in a short time in order to exploit the business opportunity on the market. Unlike traditional environments in which WFMSs are applied, virtual processes are usually non-deterministic and involve many tasks performed in parallel. In addition, the high complexity and granularity of the virtual process are driving the need for a workflow schema accessible at different levels of detail.

To assess the workflowability (the suitability for a process of being managed by means of a WFMS) of a virtual enterprise, it is useful to take into consideration its main features as identified in Section 2. Table 1 shows the impact of any characteristic on the workflowability (wfa). To have an higher level of detail the concept of workflowability has been decomposed in sixteen criteria as proposed in [1]. Every criterion has a direct impact on wfa (i.e. the higher the criteria, the higher the wfa). The assessment of a feature's impact on criteria has been based on a qualitative analysis of each feature. A quantitative analysis is planned and it is being set-up (mainly by means of questionnaires and interviews to the managers and the workers of virtual enterprises). However, it is possible to guess that the proposed table is a good approximation of the reality (on average, the impact of a feature on a criterion should be sufficiently clear).

<table>
<thead>
<tr>
<th>Effects of the features of the virtual organization (horizontal) on the workflowability (wfa) criteria (vertical)</th>
<th>Predictability</th>
<th>Repeatability</th>
<th>Automation</th>
<th>Work distribution</th>
<th>Opportunity</th>
<th>Idling</th>
<th>N. persons</th>
<th>Amount of work</th>
<th>Error</th>
<th>Control</th>
<th>Electronic support</th>
<th>Responsibility</th>
<th>Tracking</th>
<th>Quality</th>
<th>Constraint</th>
<th>Coverage</th>
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<tbody>
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<td>Market-driven cooperation</td>
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<td>Complementarity</td>
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<td>Dynamic participation</td>
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<td>Legal &amp; economic independence</td>
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<td>Process &amp; resources sharing</td>
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<td>Time limitation</td>
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<td>Transparency</td>
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<td>Polymorphism</td>
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<tr>
<td>Automation</td>
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</table>

Table 1: Impact of Main Features of a Virtual Enterprise on its Workflowability
Table 2: Workflowability of the Virtual Enterprise.

<table>
<thead>
<tr>
<th>WFA Criteria</th>
<th>Impact</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictability</td>
<td>Very Low</td>
<td>Single tasks to be performed are usually not precisely defined <em>a priori</em>. It does not exist a linear path of activities development.</td>
</tr>
<tr>
<td>Repeatability</td>
<td>Very Low</td>
<td>The virtual enterprise is temporary, hence it is possible that every process is repeated just for a limited number of cases (even just one).</td>
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<tr>
<td>Opportunity</td>
<td>Low</td>
<td>The virtual process involves applications that are not easily implementable (they are heterogeneous, distributed and autonomous).</td>
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<tr>
<td>Automation</td>
<td>High</td>
<td>The automation of the Workflow is desirable and may have a strong impact on inter-organizational processes performances.</td>
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<tr>
<td>Number of Persons</td>
<td>High</td>
<td>Many people from different organization are working together. These persons may have different working styles and may not trust each others.</td>
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<tr>
<td>Amount of Work</td>
<td>High</td>
<td>An intense amount of work is necessary in particular time frames.</td>
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<tr>
<td>Electronic Support</td>
<td>High</td>
<td>ICT is a key resource both to share information and to synchronize tasks.</td>
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<tr>
<td>Responsibility</td>
<td>High</td>
<td>The task distribution needs to be bundled with the distribution of the responsibility on it.</td>
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<tr>
<td>Work Distribution</td>
<td>Very High</td>
<td>Since many organizations cooperate in the virtual enterprise, it is necessary to effectively share authority and responsibility on activities.</td>
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<tr>
<td>Error</td>
<td>Very High</td>
<td>The virtual process is complex and distributed, hence many errors are likely to emerge.</td>
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<tr>
<td>Control</td>
<td>Very High</td>
<td>The control of the process is a difficult task because of the large number of cooperating enterprises and the distribution of tasks.</td>
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<tr>
<td>Idling</td>
<td>Very High</td>
<td>Inter-organizational processes are difficult to synchronize, then it is possible that bottlenecks emerge.</td>
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<tr>
<td>Tracking</td>
<td>Very High</td>
<td>It is necessary to define, control and manage intermediate goals (also by means of check-points and milestones).</td>
</tr>
<tr>
<td>Quality</td>
<td>Very High</td>
<td>The quality of both sub-processes and sub-outcomes is necessary and difficult.</td>
</tr>
<tr>
<td>Constraint</td>
<td>Very High</td>
<td>The process constraints are specified by the client and have to be applied precisely and effectively.</td>
</tr>
<tr>
<td>Coverage</td>
<td>Very High</td>
<td>The whole process must be headed to the customer satisfaction.</td>
</tr>
</tbody>
</table>

The overall impact of the main features of the virtual enterprise on the wfa criteria is then shown in the table 2. Despite its low predictability and the possibility that it could be performed a limited number of times, the virtual process will in general take advantage of a WfMS mainly because of the importance of resource integration and of data, information and task coordination and synchronization. Hence, Workflow systems for the virtual enterprise have many peculiarities [7][8][9] and cannot be managed by means of traditional WfMS.

However, we must take into account that the implementation of WfMSs in the virtual enterprise is hindered by many different inhibitors, e.g. the risk of opportunistic behaviors of partners, the non-determinism of the virtual process and the non-linearity in the flow of tasks, the need for a tight control on the process, the likelihood of exceptions manifesting themselves and the importance of efficiently handling them [7][11].

5. Organizational Configuration

To fully exploit the potentialities of the proposed approach to business process integration we focused our attention to the organizational configuration of the virtual enterprise. In a complementary research, [2] introduce a virtual enterprise organizational configuration based on three key roles that the member organizations may play in the virtual enterprise (EBC model): (a) organization enabler, (b) process catalyst, and (c) broker.

In the ECB approach, the enabler paves the way for the cooperation, it is an “institutional”, super partes entity. Any firm (within the sub-environment managed by the enabler) foreseeing a business opportunity on the market, can become Catalyst, initiating the virtual enterprise and taking in charge all customer relationships. The Broker is the entity in charge for the coordination of the business process.

Main perceived benefits of the ECB approach are: effective management of horizontal and vertical inter-relationships, efficient set-up of the virtual enterprise, effective management of its operational phase.

6. Discussion and Conclusion

Although potentially very efficient, implementation of WfMSs in the virtual enterprise is hindered by many different inhibitors, e.g. the risk of opportunistic behaviors of partners, the non-determinism of the virtual process and the non-linearity in the flow of tasks, the need for a tight control on the process, the likelihood of exceptions manifesting themselves and the importance of efficiently handling them [7][11].

Hence, workflow systems for the virtual process should be charactherized by special features [7][8][9]:

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- **Ease of use**: the efficiency of the virtual process may depend also on the time spent in learning how to use the workflow system, hence it has to be easy to learn and ergonomic to use.
- **Synoptic but Formal Description**: to ensure an easy implementation and adaptation it should use simple but effective graphic notations; however, it should be able to precisely formalize some key variables of the process.
- **Universality**: it has to be able integrate and allow resource sharing and enactment of heterogeneous WfMS.
- **Modularity**: it should be possible to cut off PCPs at any time and to reconfigure the process as a consequence. The addition of new PCPs during the enactment should be also possible.
- **Openness**: interoperable communication and enactment standards have to be adopted.
- **Non-determinism**: it has to efficiently isolate and handle process exceptions.
- **Flexibility**: it should be able to evolve in accordance with the dynamic characteristics and requirements of the virtual enterprise.
- **Multi-detail**: it should be suitable for being developed, enacted analysed with different detail levels and it should simultaneously support both top-down and bottom-up design methods.
- **Run-time definition**: it should be able to perform the workflow schema even if the schema is not completely defined.
- **Multiple views**: integrated processes have to be accessed, analyzed and enacted with respect to different variables (time, resources, costs, etc.).

The adoption of WfMSs to manage virtual processes represents, at the same time, a wonderful opportunity and a strong challenge. A true cooperation among autonomous enterprises is achievable by developing workflow systems able to manage the virtual process as a whole.

Our research activity is now being headed towards the implementation of and inter-organizational workflow schema adhering to the specifications described in this paper and to the general specifications proposed by the Workflow Management Coalition.

### 7. References


