Integrated Modelling and Simulation of Inter-Organisational Business Processes

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OF INTER-ORGANISATIONAL BUSINESS PROCESSES

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RESUME : Le contexte industriel, caractérisé par une concurrence mondialisée, voit se multiplier l’émergence de regroupements, conglomérats ou partenariats entre des industries de type bien distincts afin d’apporter une réponse globale aux exigences du marché. Les entreprises sont conduites à inter-relier leurs processus de production, d’information, de décision, pour mettre en œuvre des réseaux de processus inter-organisationnels. Dans cette communication, nous proposons de développer une approche intégrée de la modélisation et de la simulation de processus inter-organisationnels, c’est-à-dire processus qui visent à intégrer des entreprises intervenant dans des branches industrielles distinctes (chacune caractérisée par des spécificités propres au domaine). Cette approche est basée sur la métamodélisation. En nous référant à une comparaison des concepts de modélisation et des principes de simulation dans les secteurs du service, de l’industrie manufacturière, et de la logistique, nous développons un méta-modèle intégré destiné aux processus inter-organisationnels. L’approche est implémentée sous la forme d’une maquette intégrant des environnements logiciels de modélisation standards, initialement dédiés à des domaines distincts.

MOTS-CLES: Modélisation en entreprise, Processus inter-organisationnels, Métamodélisation, Simulation, Entreprise réseau.

1. INTRODUCTION

Currently it can be noticed, that different kinds of industries are more and more joining forces to be competitive in the global market. Financial services and car manufacturing industries cooperate, e.g. to offer cars with the corresponding financing, or telecommunications and media industries work together, e.g. to provide the necessary content for the upcoming 3rd generation telecom services. As a result, the companies are connecting their business processes establishing networks of inter-organisational business processes. Process models describing business connecting different branches are mainly composed of model fragments (Lindert, Deiters 1999).

These model fragments are often described by using different modelling frameworks such as CIMOSA (AMICE 1993) or the Zachman Framework (Zachman 1987) and different modelling languages such as the IDEF languages (Menzel, Mayer 2001), UML (OMG 2001) or proprietary languages. Additionally, different evaluation and simulation techniques are used to gain information about the dynamic and quantitative behaviour of the different model fragments.

As a result, currently modelling languages and simulation approaches rarely exist connecting different branches using an integrated modelling and simulation approach. In the following we call inter-organisational processes, business processes spanning and integrating different branches such as financial services, manufacturing and logistics (figure 1). A classification schema for business processes can be find e.g. in Junginger et al. (2001).

Figure 1. The inter-organisational processes approach

In this paper we present an approach to model and simulate inter-organisational processes. In section 2 we describe some branch oriented specificities concerning modelling concepts and we introduce a meta-modelling based approach, elaborated in order to describe inter-organisational processes in a uniform way. In chapter 3 branch-specific requirements for simulating processes
2. MODELLING OF INTER-ORGANISATIONAL PROCESSES

2.1. Domain oriented modelling

As underlined in (Camarhina & al, 2001) the formal modelling of co-operating organisations must capture the collaborative organisation, which should involve an interdisciplinary approach. Several modelling approaches are currently under-development to fit such context. Some of them aim at capturing inter-enterprises co-ordination with dedicated Business Process models: such process-based descriptions can be build thanks to various methods as IDEFxx as proposed in (Presley et al. 2001) or CIMOSA (Bruno et Torchiano, 1999). Others approaches focus on reusing abilities that have to be developed in order to reduce the engineering duration. Such ability is already provided by generic models definition in CIMOSA (Vernadat, 1999) or GERAM (IFAC-IFIP, 1999) but it still requires a more precise definition of partial models documentation and interface to provide global consistency. Distributed collaborative architecture can also couple formal and informal co-operation providing that each node of a cooperative network integrates formal exchanges (as in an EDI framework) and offers security and co-ordination features as in the PRODNET architecture (Camarinha-Matos et al., 1998).

Each of the existing methods emphasises a particular types of requirements, and the modelling activity for inter-organisational modelling can still be enriched by an integrating process aiming at capturing the best of the different views (Kosanke et Nell, 1999). On the conceptual level, such a modelling framework can be provided by GERAM (IFAC-IFIP, 1999) which organises the enterprise modelling activity according to several facets and allows the use of different modelling methods and tools to fit the best modelling requirements. Unfortunately, GERAM seems to keep quite conceptual up to now. In that paper, we provide a contribution to build a pragmatic approach of such integration. To present that approach, we identify below the common properties and the differences of varying business process modelling concepts of three different branches, namely the services sector, the manufacturing sector, and the logistics sector.

Table 1 syntheses some key elements of the positioning of the three modelling domains mentioned. Service enterprises and manufacturing industries usually don’t use modelling and simulation tools at the same level of performance management (granularity level) and thus they don’t focus on the same type of performance factors as we detail below.

| Service area | Material flows and transformations (use of tools like Arena, Sector Process, PrimeObject,…) | Granularity level: high. | Main construct: “activity” and their temporal changes of status | Major type of performance considered: organisational performance; performances are measured on the activities. | Main performances factors: constraints emerging from temporal coordination of activities. |
| Manufacturing industry | Plant design, technological deployment design, performance improvement of material flows and transformations (use of tools like AREONIS, ARIS Toolset, IDEF Suite,…) | Granularity level: far more detailed than in service area (operational control level) | Main construct: “material flow” or “information flow” (linked with constraints on “material or informational entities”, and their temporal change of status) | Major type of performance considered: technological performance; performances are measured on the flows transformed by the activities. | Main performances factors: technological resources and their constraints |
| Supply chain industry | Design and optimise multi-enterprises supply chains, at different levels of decision (Ex : SCOR model). | Granularity level: necessary use of both previous granularity levels (aggregated level of the service area linked with detailed level of manufacturing area). | Major type of performance considered: logistic performances. | Specific performances factors: Geographical constraints, characteristics of transport resources, mixture of human and technical actors. |

Table 1. Three business domain, with specific modelling characteristics
2.2. Business Process Modelling in Service Organisations

In the service area (banks, insurances, telecommunications, public administrations, etc.), Business Process Management (BPM) is a very common approach used to improve productivity and internal organisation. Within BPM, modelling is used (i) to understand the existing organisation (as-is models), (ii) to evaluate critical processes and to identify those variables which can interfere on their performances, and finally (iii) to design the new deployment of those processes (to-be models). Modelling is far more used than simulation, which remains hardly integrated among the operational tools used by consultants or organisational departments. Most of process modelling in BPM is based on flow charts and activity diagrams (Tenner 97).

Our analysis of BPM modelling tools shows that the concept of "activity" is the central construct for modelling. Indeed, performance indicators and productivity improvement depend on the temporal change of status of the activities, and on their good synchronisation and coordination. Thus, in the design of an organisation the priority must be given to those constraints which emerge from the coordination of activities.

Besides, it is important to underline that models in BPM rarely use the concept of "material flow", since activities are mainly administrative and they process information. Consequently, the material and geographical constraints linked to technological resources, their impact on performances, and the operational constraints induced by the technological processes which transform a material product are seldom taken into account in the modelling process: in the service domain, such parameters are kept off the area of management.

2.3. Business Process Modelling in Manufacturing Industries

In manufacturing industries, modelling is used in various applications. It is often used to implement informations systems. In that case, information flow charting tools and activity diagrams are relevant as well as for service organisations, using tools such as ADONIS, ARIS Toolset, the IDEF Suite, etc. In regards with the previous case, those business charts usually use more technical view: an important notion is the construct of "event" which is central to represent the complexity of temporal coordination within manufacturing processes (cf. the event-driven process chain diagram used by SAP). Furthermore, modelling is also often used for more complex problems of plant design, technological deployment of workshop, or performance improvement of material flows. In that case, modelling is directly linked with simulation capabilities used to evaluate performances, using tools such as ARENA, PrimeObject, Scitor Process, etc.

Thus, in that second application field, the central concept is no more the activity but the "material flow" (it is usually represented with constructs like "entity" or "product"). Here the industrial performance directly depends on the coordination of the material flows and on the change of status of the "material entities". Generally, performance indicators are not defined by measures on the activity but rather by direct measures on the flows transformed by activities. The productivity factors are not the same as in the service area; specifically modelling constructs useful to represent the technological resources, their individual performances, and the constraints linked to their material set up, are used.

Moreover, a more detailed modelling level is used. Indeed, in the manufacturing industry structured methods to enhance total quality and high level of reactivity have induced a very accurate control of performance factors. Thus, the granularity level of the models used in manufacturing industry is far more detailed than in the service domain. It corresponds to a more operational control level.

2.4. Business Process Modelling in Supply Chain Industries

More recently the supply chain area also produced important works on modelling, particularly with the SCOR model which is already integrated in some modelling environments such as ADOlog (Lindemann et al. 2002). Logistics models share common features with each of the previous two models: on the one hand they fit to modelling levels (and thus decision levels) very similar to the service area's models (quite aggregated level); on the other hand, they represent material flows in which performance parameters linked with technological resources and processes have a great impact.

Major distinctions of process modelling in the supply chain industries in comparison to both other sectors are the consideration of geographical constraints, the kind of mixture of human and technical actors, and the characteristics of transport resources.

2.5. Assessment

Based on that comparison of the before-mentioned areas, we can underline four main issues required to support inter-organisational process modelling:

1. Depending on the application field, the modelling process deals with different decision and control levels. An integrative modelling environment must provide a consistent interaction between those different levels.
2. In each application field, the process of modelling structure and behaviour of a firm requires distinct key concepts. Although those key concepts can be linked with one another, they induce various aims of the modelling process, distinct performance objects, different control modes, and distinct modelling procedures. Thus the decision aid tools must adapt to such variety. That integration can be provided by the management of multiple views of enterprises (Presley et al. 2001), allowing the definition of various views on the same modelling object.

3. Apart from the key concepts, each application field requires also to use some specific modelling objects in order to refine the modelling for a specific domain oriented decision aid. To match that requirement, a modelling environment must be based on high modularity capabilities, allowing the use and the integration of different modelling libraries.

4. Furthermore inter-organisational firms’ networks require than the mere coordination of their business processes: they need to define a cooperation protocol which can link firms in the long term evolution, requiring to define formally common aims, distributed roles for the organisations, control of collective performances, coordination and evolution of competence fields. Thus, apart from the integration of domain oriented business processes, the management of networks of firms requires a modelling frame for organisational architecture design, using advanced concepts such as: roles, cooperation protocols, coordination mechanisms, competencies.

2.6. Integrated Modelling Approach for Inter-organisational processes

According to (ENV 40003), a process model can be described by different views. To support the design, the simulation and the management of enterprises models, we consider two distinct levels of views (see figure 2). The “Business modelling views” aim at creating the models necessary to describe the organisation and behaviour of a firm (with the functional view to describe the activities and subprocesses; the dynamic view to model the control and information flow; the organisational view to describe the actors and resources needed to execute the process; and the content view which describes the artefacts processed into products). But to support also the simulation and the life-cycle management of the models we also define “Models management views” (quantitative view to describe the necessary statistical information and change-oriented view the life-cycle of a model).

Based on that notion of views, our objective is to integrate inter-organisational models using different constructs in each view, as we assessed before. To proceed to such integration, we are using a meta-2-model (meta-meta model) which provide a generic model of all the potential views. The meta-2-model consists in a metamodelling language including generic concepts such as "model type", "view", "pattern", "class", "relation", "attribute" etc. We use that metamodelling language (or meta-2-model) to create new meta-models dedicated to specific domains (Figure 2).

A dedicated meta-model describes a domain-oriented modelling language by instanciating the generic concepts of the meta-2-model to concrete modelling concepts such as "business process model", "dynamic view", "activity", "control flow", "material flow", "execution time" etc. The final business models describing a firm will be a further instanciation of that dedicated meta model. To address modelling of inter-organisational processes we are currently building a meta-model describing the integrated business process modelling concepts for various branches. The first version is presented in figure 3.
3. SIMULATION OF INTER-ORGANISATIONAL PROCESSES

Simulation has shown to be an appropriate mechanism for the dynamic and quantitative evaluation of business process models (Herbst et al. 1997). In the following we will specify the specific simulation requirements of the three industries under consideration. These form the starting point to formulate requirements for simulating inter-organisational processes.

3.1. Business Process Simulation in Service Organisations

Many simulation environments were be developed for the manufacturing area. But processes in the services sector differ from processes in the manufacturing and supply chain sector (see chapter 3). Thus there are specific simulation requirements for services processes. In many cases the customer is directly or indirectly involved in the execution of activities. His influence must be considered accordingly. The assignment of activities to (human) actors is often done by the actors itself instead by an optimising algorithm. Additionally, this assignment is mostly more complex, e.g. in cases of substitute rules. Also, activities can be executed in a cooperative way instead by a single actor, e.g. common meetings, workshops, and presentations. The interruption of activities have to be handled carefully, if humans are involved in activity execution, e.g. call centre agents cannot simply interrupt telephone calls or nurses cannot finish medical treatments of patients although their work time has finished. In comparison to manufacturing processes, where execution times of activities are nearly constant, execution times for activities in service processes are highly volatile because they often depend on the actor’s skills and experiences executing an activity. Finally, usability of simulation algorithms has to be very high, because the amount of persons with detailed simulation skills is much less than for e.g. in the manufacturing.

3.2. Business Process Simulation in Manufacturing Industries

In comparison to the services and supply chain sector, discrete event-driven simulation has much more gained currency. The focus is on simulating production lines and complex manufacturing processes. The direct involvement of the customer in the execution of activities (normally) can be ignored. Machines are much less volatile in the execution time of an activity, because they provide a nearly constant service time even if the workload is very high. However the simulation mechanisms must be able to take into account random phenomena linked with the functioning of technological resources: the level of modelling of such phenomena is very precise.

On the temporal point of view, the simulation algorithms must not only be able to control the change of status of activities, but it has also to control the transformation and change of status of the material entities processed by the activities. The direct simulation of material flows allows to control dynamically manufacturing parameters such as batches and stocks which have a strong impact on the global performance of the system. Human resource is also an important performance parameter: the polyvalency of the operators as well as their level of competency has to be taken into account dynamically during the simulation.

3.3. Business Process Simulation in Supply Chain Industries

In the logistics sector the application of mathematical simulation and optimising approaches found great attention. These approaches focus on the operational level to plan optimised routes, shortest paths etc. and are
applied to find local optima within a single company. Current developments to global supply chains, sometimes even called supply webs, led to the need for evaluating the whole chain, including the upstream and downstream partners, the integrated inventory management etc. Strategic planning of partnerships and the design and evaluation of new types of supply chains gets into attention.

Common to the services sector, the execution time of an activity depends highly of the executing actor. Additionally, the usage of different resources influences the execution time considerably, e.g. using car or ship for transport activities.

4. IMPLEMENTATION OF THE INTER-ORGANISATIONAL APPROACH

4.1. Modelling tools integration

As reference implementation of the inter-organisational processes approach, an interface prototype between the two complementary modelling and simulation tools ADONIS and ARENA has been developed. Both tools have their respective strengths in different areas. While ADONIS is primarily intended for the modelling of activity based organisational processes, ARENA mainly focuses on the modelling and simulation capabilities of material flow based processes.

ADONIS has a powerful meta²-model that allows using the tool for a large variety of different modelling purposes. The software is completely independent from the used modelling methodology and can easily be customised to meet the user’s particular needs. Its simulation engine is optimised for activity based discrete event-driven models. Different model types, inter-model references, the tight direct coupling between a modelled organisation and its processes, the possibility to build complex model hierarchies, its documentation generation functionality and its network capability have driven ADONIS to be one of the products of choice in the services sector.

On the other hand, ARENA has its strengths in the field of simulation of complex industrial processes. It supports the notion of flows in models, i.e. it is well suited to control the transformation and the change of status of material entities processed by the different stations (activities) in a model. Its simulation engine is based on the SIMAN (Simulation and Analysis) methodology.

The ADONIS simulation engine does not focus on material flows and entity flow based processes. While ARENA offers such a simulation engine, it lacks functionalities to integrate technical process models in a company’s overall process architecture as required by the inter-organisational modelling approach. Administration and maintenance of models is much easier using ADONIS because it uses a database as repository while ARENA is file based.

Each product offers outstanding possibilities in its respective use area. Together they enhance each others functionalities to form a single solution. ADONIS is the choice for the modelling and simulation of organisational processes as they appear in the services sector and it is used to integrate ARENA’s technical models into an overall business process architecture. ARENA enhances the modelling capabilities of ADONIS by providing a powerful simulation engine that supports the notion of flows.

4.2. Implementation architecture

The interface between ADONIS and ARENA is bidirectional (i.e. models can be exchanged in both directions: from ARENA to ADONIS and vice versa) and it is completely independent from the used modelling methodologies. To achieve this flexibility, a methodology dependent map file (table of correspondence) has to be provided when a model of one tool is converted to the other tool’s model format (figures 4 and 5).

As shown in figure 4, the interface converts between ARENA models described in XML into ADONIS models described by an ADONIS Definition Language (ADL) file. The interface consists of two parts. First, there is an add-in for ARENA that allows importing and exporting models from/to XML. The converter, which is the interface’s main part, translates between ARENA and ADONIS models. Then, the necessary information
how to map objects and their attributes from one model type to the other is obtained from a map file, which is also XML based.

In order to include ARENA simulation results into the overall process documentation and to aggregate them in higher hierarchy level models, it is possible to export these results to ADONIS as well. The simulation data is obtained from a database that is generated during an ARENA simulation run. In ADONIS the simulation results are directly available as an attribute of those objects that produce the corresponding results (figure 6).

5. PRINCIPAL BENEFIT FOR THE USER

The user of the tools ADONIS and ARENA can take advantage of the described interface in order to combine his organisational and technical process simulation with his modelling needs. He can create and maintain all the models in a single environment (ADONIS) which makes easier the models maintenance and administration. If he needs simulation data from material entity flow based technical models, he can export the desired models to ARENA and re-import the generated simulation results into ADONIS' models.

6. OUTLOOK AND FUTURE WORK

In that paper we developed a contribution to a business process based approach for the design of organisations. In that approach we assert that the best way to model organisations is to consider them as networks of business processes, which are linked to each other by trade relations. The modelling and simulation environment we are working on aims at integrating different types of business processes: we showed that such integration is rather complex because of distinct requirements for modelling, as well as for the simulation of those various types of processes.

The research results explained in that paper show the conceptual and technical possibility of building an operational link between two complementary modelling and simulation tools: ARENA was chosen as a tool used in the manufacturing area, when ADONIS is mainly used in the services sector. Some further work has already been launched:

- In the conceptual part of the paper we insisted on the need to integrate 3 main areas: services, manufacturing, logistics. The application developed in section 5 only presented results on operational integration of two fields. The integration of the logistic modelling and simulation area is actually under work using the SCOR model and ADOlog (Lindemann et al., 02).
- We underlined in conclusion of section 3 the need of a modelling frame for organisational architecture design. The conceptual definition of such a frame is actually under work at the Ecole des Mines de St Etienne.

7. LITERATURE


