Interactive Models for Supporting Networked Organisations

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Abstract. This paper presents a novel approach to the development and operation of dynamic networked organization. The approach is based on the idea of using interactive models. Interactive models are visual models of enterprise aspects that can be viewed, traversed, analyzed, simulated, adapted and executed by industrial users as part of their work. The approach was developed in the EXTERNAL-project, where experiences from three case studies were used as a basis for validation and further enhancement of the approach in follow-up projects. The main innovative contributions include an environment to support concurrent modelling, meta-modelling, management and performance of work, integrated support for planned and emergent processes, and customisable model- and process-driven integration.

1 Introduction

The business environment is getting increasingly dynamic and complex. Co-operation across traditional organizational boundaries is increasing, as outsourcing and electronic business is enabled by the Internet and other information systems. As a consequence of this, organisations are becoming less self-sufficient and increasingly dependent on business partners and other actors. When such co-operation moves beyond the buying and selling of goods and well-defined services, there is a need for a flexible infrastructure that supports not only information exchange, but also knowledge creation, evolution and sharing.

A dynamic networked organisation (DNO) is being developed more or less ad-hoc to reach a certain goal based on the resources of several co-operating enterprises. Such networks consist of independent partners, unlike top-down virtual enterprises where the main partner lays down the rules for coordination, e.g. in outsourcing. The partners often come from different countries, using different languages and having different cultural background. They aim to harvest knowledge from the DNO to be reused in their traditional organization, and in other DNO's.

The approach and working environments to enable this must allow dynamic, concurrent execution, modelling, and meta-modelling in distributed teams. This demands a new approach to enterprise integration and system engineering, which will be described in this paper. We first present the concept of interactive models. We then outline the EXTERNAL IST-project [3], and the 3 layers of infrastructure that this

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project provides to support this thinking. Major aspects of the infrastructure are presented, and a case study shows the feasibility and usefulness of the approach. Finally we briefly position interactive models in context with related work, and point out directions for further research.

2 Interactive Models and the EXTERNAL Project

An interactive model is a visual externalization of enterprise aspects that can be viewed, traversed, analyzed, simulated, adapted and executed by users [16]. What does it mean that the model is interactive? First of all, the visual model must be available to the users of the underlying information system at runtime. Second, the model must influence the behaviour of the computerised support system. Third, the model must be dynamic, users must be supported in changing the model to fit their local reality, enabling tailoring of the system's behaviour. Users thus manipulate and utilise interactive models as part of their day-to-day work.

2.1 The Interactive Model Approach

Utilisation of interactive models implies that modelling, meta-modelling and work can be performed in parallel. To support this in practice is dependent on a rich, generic infrastructure. Being able to support collaborative work and managing knowledge will decide the quality of the solution. The usage and value of the approach also depend on the competence and knowledge of the teams involved.

2.2 Concurrent Meta-modeling, Modeling, Work Management and Performance

One of the cornerstones of the approach is to integrate learning and knowledge management into everyday work and management *practice*. This is supported through supporting concurrent definition of extensions of modelling language (meta-modelling), modelling and planning of the work, model-driven management, coordination, and performance of work. There is thus a direct link from knowledge management activities to work performance, as depicted in Fig.1.

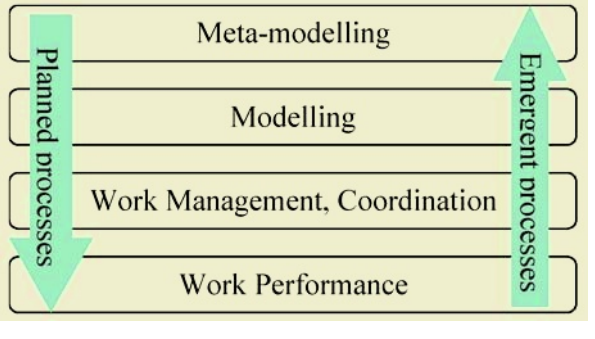

Fig. 1. Concurrent meta-modelling, modelling and work performance

2.3 Planned vs. Emergent Processes

Most process support systems target planned processes, where generic models of work are applied to several instances of projects. Models are constructed prior to work performance, and not expected to change much during performance. A number of case studies have demonstrated the limitations of this approach. It often leads to models that do not accurately depict the way work is actually performed [18], and models that bias a management perspective at the expense of work performance [21]. Such models can cause constraining more than facilitating tool support, and are poor resources for process improvement. Consequently, our approach also supports *emergent* processes [8], processes that are represented by evolving models, where local changes are allowed and supported. All real work processes have aspects and parts that are best described as emergent, but also aspects and parts that can be thoroughly planned in advance. It is thus necessary to integrate the support for both kinds of processes if we are to provide an infrastructure for knowledge-based networked organisations.

2.4 Process and Model Integration

Models and processes are the core means of integration in the approach, both vertically and within each layer in Fig. 1. Meta-models define the language for modelling, and models define the work processes to be performed and managed. For emergent processes, modelling may be intertwined in the performance and management of work, bringing local knowledge into more detailed and accurate plans. By developing and sharing models of their joint enterprise, participants in a networked organization construct shared understanding at the levels of work and management, but also the language and models for their internal communication.

Process integration is an important aspect of reflection in the approach. Through modelling and management, the primary work is articulated, controlled and coordinated. But modelling and management are themselves work activities, thus models of how we perform the processes of modelling, project planning, follow-up and coordination are defined. These models customize and guide the modellers and managers through their work just like the primary models support those performing that actual work of the networked organizations. In the approach work and knowledge management is thus supported just like other work activities.

3 Overview of the Infrastructure Layers

The infrastructure to support networked organisations developed in EXTERNAL can be described as consisting of three layers [10, 12]. These layers are identified as:

- Layer 1, the *information and communication technology* (ICT) layer: – defining and describing the execution platform, software architectures, tools, software components, connectivity and communication.

- Layer 2, the *knowledge representation* layer: - defining and describing constructs and mechanisms for modelling.
- Layer 3, the *work performance and management* layer; - modelling and implementing customer solutions, generating work environments as personalized and context-sensitive user interfaces available through portals, and performing work.

3.1 The ICT Layer

The ICT-infrastructure is an integration of the enterprise and process modelling tools brought into the EXTERNAL project by the partners:

- METIS [15], a general purpose enterprise modelling and visualization tool,
- XCHIPS [6], a cooperative hypermedia tool integrated with process support and synchronous collaboration,
- SimVision (previously Vite) [14], a project simulator used to analyze resource allocation, highlighting potential sources of delay and backlogs.
- WORKWARE [7, 8], a web-based emergent workflow management system with to-do-lists, document sharing, process enactment and awareness mechanisms.
- FrameSolutions [9], a commercially available framework for building automated workflow applications.

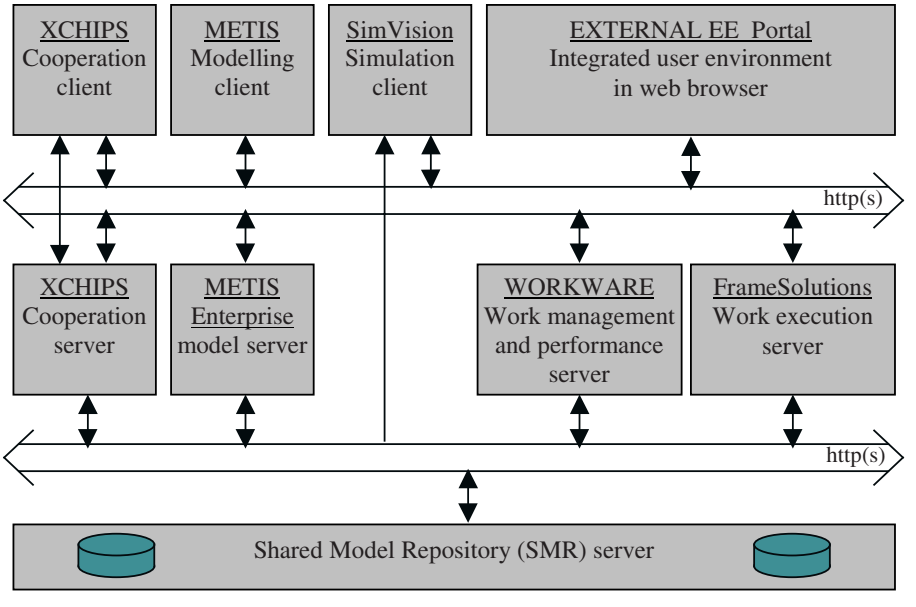

Fig. 2. The architecture and components of the EXTENAL infrastructure, ICT layer

Fig. 2 depicts the technical infrastructure. The architecture has 3-tiers, clients, application servers, and data servers. The implementation is web-based, utilizing HTTP both for control and data integration, and exchanging data with XML format. The integration work has proceeded in three steps.

1. Data-centred integration: based on a common EXTERNAL XML DTD, XML importing/exporting utilities are implemented in each of the enterprise tools for data exchange between the tools or between an XML repository and the tools.
2. Control-centred integration: this is done by using the APIs provided by the tools and the repository to be integrated. With the APIs, the tools can call each other and access the shared repository. Some of the APIs may have parameters for denoting content objects and the implementation of them requires the data-centred integration capability as developed in step one.
3. Worktop-based integration: this is a service-based integration at the user-interface level which makes use of both data-centred integration and control-centred integration methods to access shared models, information objects, and to invoke individual tools.

3.2 The Knowledge Representation Layer

The knowledge representation layer defines how models, meta-models and meta-data are represented, used and managed. A version of Action Port Modeling (APM) [1, 8] constitutes the core of EXTERNAL's modelling language (EEML). The kernel concepts are shown in Fig. 3 as a simplified logical meta-model of EEML. The process logic is mainly expressed through nested structures of *tasks* and *decision points*. The sequencing of the tasks is expressed by the *flow* relation. *Roles* are used to connect resources of various kinds (people, organisations, information, and tools) to the tasks. Hence, modelling the networked organisation in EEML results in models that capture an extensive set of relationships between the organisations, people, processes and resources. This is particularly useful considering the dynamic nature of networked organisations. For new partners joining the network, the rich enterprise models provide a valuable source of knowledge on how to "behave" in the network.

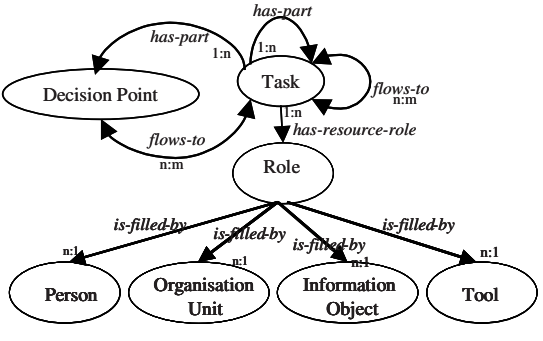

Fig. 3. Simplified meta-model of EEML

Moreover, the interactive nature of the models, meaning that the users are free to refine them during execution, increases their potential as sources of experience and knowledge. As such they *document* details on how the work was actually done, not only how it was once planned.

The notation of the main concepts within the language is illustrated in Fig. 4 which consist of a conceptual meta-model of EEML. In addition to the core concepts of tasks, decision points (including milestones) roles and resources, it illustrates support of goal modeling and competency modeling.

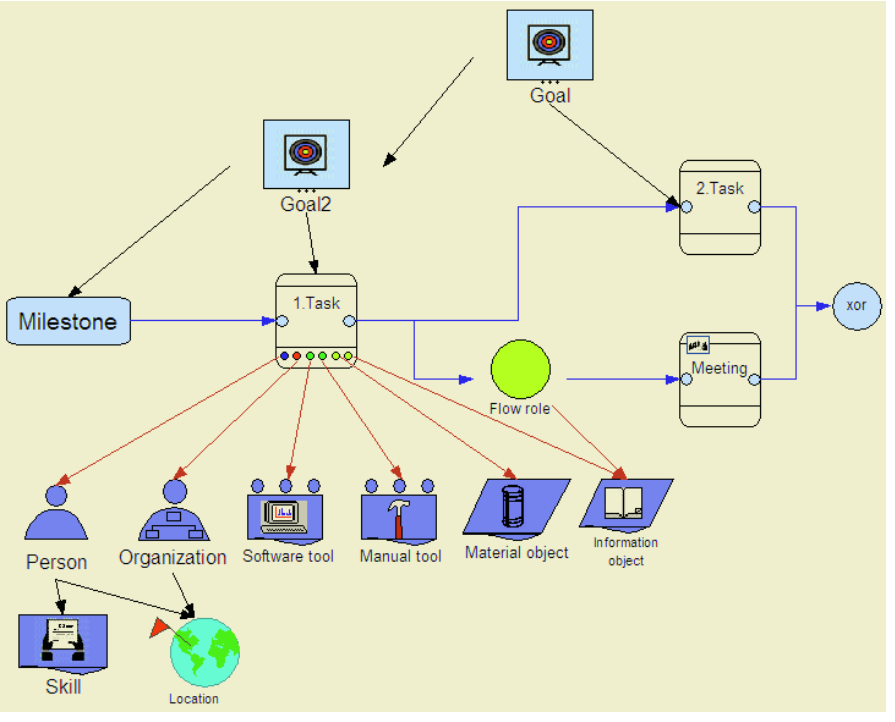

Fig. 4. Conceptual meta-model of EEML

From a knowledge management perspective, process models are carriers of process knowledge; knowledge of how to do things. But through the possibility in EEML of attaching information resources to the tasks at any level, such a model also imposes a structure upon the set of information resources relevant for the work described by the process model. That way, the process models themselves form the basis for information management.

3.3 The Work Performance and Management Layer

Users access their solutions through project portals. A project portal for a networked organisation must have support for methodology adaptation and for communication, co-ordination and collaboration in teams. Project work management, reporting and other services must be offered, and finally project work must be performed with possibilities for repetition, providing security and privacy to knowledge workers.

In the EXTERNAL infrastructure, the web-based portal registers and qualifies users, and invokes other tools through WORKWARE. The modelled tasks are also executed through the invocation of tools and applications from the web based user envi-

ronment comprised of the portal and WORKWARE. WORKWARE sets up the context for each task, giving access to the knowledge and resources needed to perform the task. The actual work performance is done by invoking appropriate services. The task performers may access desktop tools, organisational information systems, web services, or automated processes (in FrameSolutions) through this user environment.

User environments are generated dynamically based on the definition of tasks using EEML. Forms and components for interacting with different model objects are selected and composed based on user interface policies. These policies are also modelled objects. This enables user interface customization and personalization.

The dynamically generated work management interface (lowest level) includes services for work performance, but also for process modelling and meta-modelling. The *worktop* is the main component in this interface. Each task has its own worktop. In addition to the services for performing and managing the task, it contains links to all knowledge in the process models that is relevant for the task. Since the worktop is dynamically generated, subject to personal preferences, the skill levels of task performers can be taken into account, e.g. to provide more detailed guidelines for people who have not previously worked on such tasks. Similarly, customized worktops for project management can support the project management team. The contents may include an overview of the project, adopted management principles, applicable methodologies, project work-break-down structure, results, plans and tasks, technologies and resources, status reporting and calculations.

4 Case Study: Project Planning and Performance

In the EXTERNAL project, a number of case studies have been used to explore the feasibility and usefulness of the approach and the current infrastructure [3, 17] including research projects and industrial cases from a network of small and medium sized IT companies, and from business consulting. In this work, the situated knowledge we can capture from user experiences, methodologies, and models, is complemented by a formal evaluation [17].

4.1 Joint Project Planning (JPL)

Project planning is a knowledge-intensive task, which utilizes the process modelling tools for work performance. The first implementation of this case included the *plan* (a process model) as well as the *planning process* (meta-process), but not the operation of the plans once they were completed. Both the plan and the planning process were modelled in EEML. In advance, it was expected that the need for coordination between different work package plans would require the real-time collaborative modelling services of XCHIPS. Consequently, this tool was selected as the main worktop for this task. XCHIPS support more focused collaboration than the web-based portal environment provided through WORKWARE. When two people work on the same task, they immediately see the effects of each others' actions. The interface provides real-time awareness of who is currently working in the process, in addition to showing the current status of the tasks by colour coding as in METIS and WORKWARE. The use case report contains an example of how these features were utilized for defining a template [5]:

Once the joint planning process model was finished, one designer created a work package model template [in] the METIS modelling environment and made the template available by using the shared repository [...] Subsequently, she put a link to the template into the JPL process model. Now, another designer used that template to create a sample work package model for WP 4, by using modelling services. This model was reviewed by the first designer and improved during a number of iterations. The final example model was made available in the shared repository and linked to from the JPL process model.

This mixture of largely asynchronous work and some synchronous discussions was greatly facilitated by the shared repository, collaboration, and modelling services.

The template produced here is a typical example of a process model. It includes a basic structure for objects, with separate folders for tasks, inputs, outputs, organizations and people, as well as a project document archive. Many elements, e.g. parts of the archive and the organizational structure, are shared among the different work packages. The organization of the models into folders facilitated such sharing and reuse. The inputs to one work package (WP) in many cases are the outputs of another. At the same time, the separation of responsibility among WP managers is reflected in the granularity of the process models, with each WP articulated in its own model. The poor support for relationships between model files is currently a major limitation of the EXTERNAL infrastructure. At the same time the modularization of models in this case simplified the modeling work for the WP managers.

This example shows how (meta) process support can facilitate knowledge management tasks. XCHIPS was also used for enacting the meta-process of defining new projects in this version of the EXTERNAL infrastructure, invoking METIS to let users define the first plan of the project and then forwarding it to WORKWARE for enactment.

4.2 Action Lists for Emergent Processes

The first implementation in the JPL case presented above took a *planned process* perspective, where managers were responsible for planning the work inside their work package. These plans, however, seldom are detailed enough to cover all the tasks that are to be performed. Consequently, the EXTERNAL project also had a web-based action list on the project web server. This solution had a number of limitations, typical for publish-oriented web solutions:

- Only the project manager could change the list,
- The actions lacked context, and were sometimes hard to understand for the persons responsible,
- The actions were not explicitly connected to project plans (the process models),
- The action descriptions contained no links to a work area or documents and tools that could be used for performing the actions,
- Although the list could be sorted on different attributes and filtered according to certain criteria, it was not possibly to add user-defined lists.

The action lists were consequently not actively used by many of the project participants. When the EXTERNAL infrastructure became available, it was thus decided to use that instead. WORKWARE has a central role in this application, managing the actions as EEML tasks. It took only two hours of work to customize a WORKWARE server for action lists. In this solution engineering process, worklists were defined that organize actions according to these criteria:

- Status, e.g. most lists contain only ready-to-be-performed and/or ongoing tasks,
- Delay,
- Work packages,
- Teams that have shared responsibility for distributing, scheduling and coordinating interrelated tasks across work packages,
- Persons, separating the actions which the current user is responsible for from the ones where she is just a participant,
- Follow-up lists, containing all tasks that the current user is customer of. Lack of follow-up from other people than the project manager, was reported as a major problem with the previous system.

The increased access to edit actions should make the lists more up to date. Although the structure for the actions was not connected to a full project plan, at least the work packages provided some increased context for the work. Explicit assignment of follow-up responsibility and the ability to look in the event log to see who created the action, made each item easier to understand. The old, static action lists contained 288 actions after two and a half years of operation, while WORKWARE contained 131 after just two months, even though it was installed during the summer holidays. This, as well as feedback given in meetings, indicates that the users experienced the second application as a substantial improvement.

This case demonstrates how quickly and easily interactive models can be customized to a particular usage need by defining an overall process model, a menu structure, and some specialized worklists and web services. After people started to use the application, further customization was made based on usage experiences. The case also shows how bottom-up, emergent process articulation can complement top-down planning.

4.3 Proposal Writing for an International Project

A final aspect to be illustrated here in relation to this case is the use within proposal writing for a follow-up project, involving also a number of additional partners. The process used as an outset was the methodology for planning, developing, deploying, running, and decommissioning networked organisations developed in the EXTERNAL project itself. The methodology was represented as a generic model EEML-model to be specialised as an interactive model on individual projects.

An overall plan was developed in METIS. The model is a specialisation of the proposal writing part of the generic EXTERNAL methodology. The plans were transferred to Workware, where a more detailed work-breakdown structure was developed and tasks where allocated to specific persons (see Fig. 5), acting as a support environment. The task with an id-number in the list on the left is taken from the generic model, whereas the more detailed levels are specific for this task.

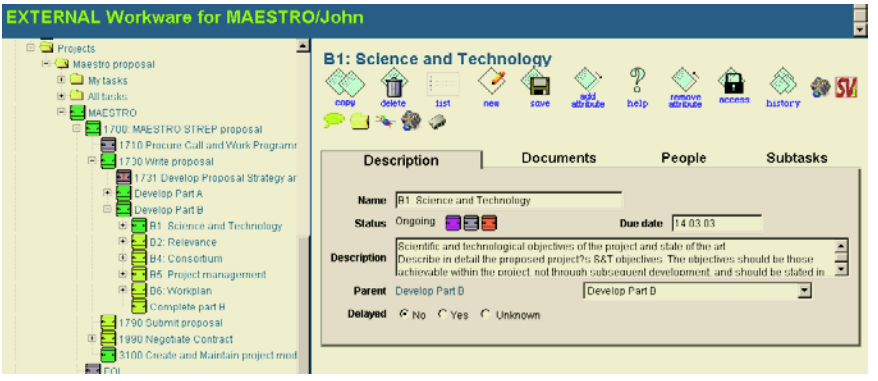

Fig. 5. Generated work environment for the proposal task

4.4 Evaluation

The experiences from the EXTERNAL cases were subject to a formal evaluation [13, 17]. An independent researcher who had not participated in the project performed the evaluation. He followed a quasi-experimental strategy measuring how participants of the separate case studies perceived their working environment, before and after EXTERNAL was implemented. A quasi-experiment resembles a classical experiment in the social sciences, since specific attitudes of a group of people are measured before and after the group is given a stimulus believed to impact on these attitudes. However, in a classical experiment the attitudes of a control group (that is not given the stimulus) are compared to the group that is subject to the stimulus. In addition, both the experimental group and the control group are selected by randomisation. Our evaluation did not encompass a control group and the respondents were not selected by randomisation, hence it is a quasi-experiment.

In order to provide the best possible basis for judgement, measurements were performed by way of a structured questionnaire submitted to all case-study participants before and after the implementation of the EXTERNAL infrastructure supporting their work in the case-study. In addition, semi-structured interviews have been conducted with selected participants on all case studies. The use of interviews was performed to provide more depth and to unveil areas of improvement.

To measure the impact of EXTERNAL, we identified a set of statements indicating various attitudes towards working in networked organisations (indicators). In the surveys, 16 participants were asked to state (along a six-level scale) the extent to which they agreed, or disagreed, to the statements. To assess whether EXTERNAL have brought about changes in the way the participants perceived their work environment, a selection of these statements were evaluated both before and immediately after the implementation. The remaining statements were aimed specifically at investigating the quality of EXTERNAL and were for this reason evaluated only after the implementation. In the following section we present some main results from the survey questionnaire together with interview data. Due to space limitations, we only present parts of the results.

A literature survey led us to highlight technical viability, cost effectiveness, functionality and impact on business processes, as key dimensions for this evaluation. The

following criteria were regarded as critical enablers for these objectives: Ease of use, easy access to tools, effective communication, learning, and trust. A number of statements were used as indicators for each of these criteria, and users were asked to rate to which degree they agreed to the statements as outlined above. Agreement signifies required qualities. Table 1 gives a high-level summary with the results from the questionnaires indicating the overall positive shifts in opinion among the users.

Table 1. Summary of evaluation results (average scores)

	Number of people who agree		Number of people who disagree	
Criteria	Before	After	Before	After
Access	2,8	9,3	13	5,6
Usability	Not asked	8,7	not asked	6,6
Communication	6	12	10	4
Learning	2,4	8,8	13	7
Trust	8	12,8	8	3

Although the tendency is clear, there are also a number of limitations related to these results, including the potential for bias, and lack of control group. Still, a number of lessons can be learned especially from the supporting interviews. For instance, customisation was the area within usability that had the lowest score, but the respondents were polarised on this issue, with most people saying that they "agree a little" that tailoring is easy, while a number of people "strongly disagreed". This may reflect the fact that the customisation services, e.g. of WORKWARE, had not been made easily available to all participants. Also, no specialized customization user interface existed, other than general modelling and editing of policy data objects. Feelings were also mixed regarding simplicity and ease of use, but here the interviews uncovered that while web-based tools were rated high, other tools were not. This was part of the motivation for the later trials with action lists, and also for using the web based interfaces as front end in the second version of the infrastructure. Within communication and coordination, statements concerning overview of tasks and feedback to information showed the greatest improvements, while real-time communication seemed not to meet all expectations.

For the planning case in particular, results were mixed. Some of the respondents felt quality and effectiveness had improved, while others claimed the opposite. A clear majority however felt that the accuracy of the plans had improved. When asked what the most important problem was in planning, half of the respondent originally thought lack of joint planning. After having tried the tools, however, all but one chose "identify dangerous delays" [5]. This indicates that the tools did indeed solve some of the collaboration problems. The action lists were conceived as the next step, putting the plans into action, so it was evident than problems related to planning support were largely solved.

5 Related Work

The EXTERNAL infrastructure combines a number of mechanisms that use interactive models for customizing and tailoring the information systems.

With respect to supporting dynamically networked organizations, most B2B E-business frameworks including ebXML and BPML [20] focus on information exchange and business transactions. They lack support for the dynamic and knowledge-intensive parts of inter-organizational processes.

Enterprise ontologies have been proposed as a way of solving the communication problems arising from different interpretative frameworks in different organizations [4]. This approach is based on conventional notions of model interpretation, i.e. the Turing paradigm, where the interpretation and activation of models are fully automated. The more powerful interaction machine paradigm [7, 22, 23], allows users to influence model interpretation. The main characteristic of an interaction machine is that it can pose questions to human actors during its computation. The problem solving process is thus no longer just a user providing input to the machine, which then processes the request and provides an answer (output), it is a multi-step conversation between the user and the machine, each being able to take the initiative. Interactive models support ongoing modelling, model interpretation and activation also by the end-users, following the interaction paradigm.

Another main aspect in the approach is that the modelling languages can be updated as part of the development. This is similar to a domain specific modelling (DSM) approach [11]. However, most work within DSM is geared towards supporting technical design rather than the development and customisation of business solutions.

Workflow management systems have also been proposed as a solution for inter-organizational collaboration [2, 19]. Approaches such as ServiceFlow [24] points to the need for flexible solutions, although not taking a model-based approach. The focus of EXTERNAL on knowledge intensive processes requires a degree of flexibility not enabled by conventional production workflow systems [7, 8].

Another popular solution for cross-enterprise integration is middleware frameworks like OMG's CORBA. The recent shift in the focus of OMG to modeling (MDA and UML), standardisation of meta-object integration (MOF), business objects and workflow management indicate an interest in model-driven enterprise integration also from the more technical side. That these software engineering approaches are transferable to interactive modelling has not been shown.

6 Conclusions and Further Work

Interactive models allow enterprises and networked organisations to control and customize their IT infrastructure through visual modelling of work processes. In an integrated knowledge management framework, concurrent meta-modelling, modelling, management and work performance become interwoven, supporting both planned and emergent work tasks. The EXTERNAL infrastructure has been used in three case studies, and parts of it are also used in other commercial and research projects. It has been found adequate for building the models for use in the project, and for supporting a wide range of tasks. This demonstrates the power and possibilities of the approach in finding solutions to the industrial challenges mentioned in the introduction.

We are currently pursuing extensions and improvements to the infrastructure in a number of areas mentioned in this paper. Model harvesting and reuse mechanisms, supporting process knowledge management, are among the most challenging components to design. Further experimentation with the infrastructure in other business

domains is also planned. In particular, we will seek closer integration with existing enterprise information system in order to provide a full project environment for business users.

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