Analysing, Modelling, and Improving Workflow Application Development Processes

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Abstract: The success of workflow projects to a large extent depends on how workflow application development processes are planned, organized, and conducted. Based on lessons learned from problems encountered during real-world workflow projects, this paper presents a development methodology for workflow application development processes, which guides project managers and developers through the complex structure of these processes, aiming at developing more adequate, usable, and reliable workflow applications.

Keywords: Workflow application development processes, development methodology, case study

1 Introduction

Workflow management systems aim at the controlled execution of complex application processes in distributed and heterogeneous environments [Georgakopoulos et al. 1995, Leymann et al. 1994]. These systems are already and will continue to severely influence and shape the structure of information systems in business and non-business environments. While software development processes have been investigated for some time now (e.g., [Boehm 1981]), the specific properties of workflow application development processes (WADP) received little attention so far. This paper tries to remedy this situation by analysing problems encountered during the conduction of real-world workflow projects and by formalising the experiences drawn as a development methodology which can be adapted to the needs of particular workflow projects. While the general structure of the development methodology is based on techniques known from software engineering process models, the specific properties of workflow applications and their implications to development processes of workflow applications are well taken care of.

We now introduce basic concepts in workflow management, used in the remainder of this paper. Workflow schemas are representations of application processes and of the technical and organizational environment of their execution, to be used by workflow management systems for controlling the execution of workflows. Typically, different perspectives are covered in workflow schemas: The functional perspective describes what has to be done within a workflow. The operational perspective determines how it is done, i.e., which methods, techniques and tools are used to perform a given workflow. The behavioural perspective defines the behaviour of the workflow, i.e., it specifies when and under which conditions a workflow is executed. The informational perspective specifies the data objects which are being manipulated during workflow executions and the flow of data between workflow activities. The organizational perspective describes how the workflow is embedded in the context of the organization, both in terms of personnel and information infrastructure. This perspective is often covered by roles, which specify properties of personnel and software systems. When a workflow is performed, a technique called role resolution is used to assign persons or software systems to workflow activities. Once a workflow schema is defined, a workflow instance can be instantiated which represents a business process, e.g., the processing of an order. We denote by workflow application an information system in which work is coordinated by a workflow management system. Typically, numerous persons with different backgrounds and experiences collaborate in a workflow application. In order to develop adequate workflow applications, these persons, their skills and expertises also have to be taken into account.

Workflow applications are developed in complex processes in which numerous persons with different

backgrounds participate. While workflow application development processes differ from one project to the next, the general procedure can be described as follows [Holten et al. 1997]: The first phase deals with gathering information, relevant for the application process. Empirical studies based on interview techniques and analysis of available documentation are used. The activities in this phase are centered around the application domain, and technical issues are often not considered. The next phase involves business process modelling, in which the information gathered is used to specify business process models. The main purpose of business process modelling is to provide a general and easy-to-read notation, which enables information system experts and domain experts to validate and optimize business process models. The result of this phase is specified in a business process model, which is used as a basis for the next phase, the workflow modelling phase. Its aim is to enhance the business process model with information needed for the controlled execution of workflows by a workflow management system, involving adding technical information and purging application specific information which is irrelevant for workflow management. Finally the workflow application is deployed in the target environment, and the operational phase starts.
This paper is an extended version of [Weske et al. 1999]; its remainder is organized as follows: Section 2 briefly describes real-world workflow projects we have conducted, and it shows a set of important problems encountered during these projects. Section 3 proposes a development methodology for workflow application development processes; concluding remarks complete this contribution.

2 Case Studies

In order to create an empirical basis for our work, it is necessary to examine some of the experiences which we made in different companies when developing and introducing workflow applications. [1] For that reason, we have chosen six German as well as multi-national companies working in transportation, telecommunication, insurance and production, which were planning, developing, or which are already introducing workflow applications. In order to achieve comparable results, the investigation of the different workflow projects followed a common method.
The studies are organized in three steps: survey, modelling, and analysis. The survey step centers around interviews, with typical questions like “Which were the main objectives/results for/of your workflow project?”, “What kinds of activities did you carry out?”, “What kinds of problems occurred, and how did you manage them?” and “In a followup project, which parts of your development procedure would be subject to change?”. The information gathered is structured and serves as input for the next step, the modelling step. Its purpose is to compare the different development processes, using a development process model for each case. The analysis step aims at identifying the relationship between the main problems encountered and the way workflow applications have been developed. The detected relationships are described textually, to serve as input for the reference development process model. We now sketch key properties of these projects [Goesmann et al. 1998].
Project 1 was carried out by a telecommunications service provider. The project focused on the development and introduction of a workflow application for a core business process including the integration of several legacy applications. Due to several problems which were identified during the development, the project was delayed considerably. The main issues encountered during this project are reviewed below.
A logistics services company initiated a workflow project aiming on the improvement of customer service processes, hereafter referred to as Project 2. That workflow project was conducted using traditional software engineering techniques. When the system was operational, severe performance problems were encountered. As a result, the workflow management system was removed from the system architecture, and a new version of the application was built without workflow management technology. In Project 3, another logistics enterprise planned a workflow management application for an order processing business process. This project also suffered from delays, caused by integration problems. In particular, the requirements of existing legacy applications were not identified in early project phases, which caused considerable development overhead in later phases. In Project 4, a manufacturing company started a project to deploy a production planning and controlling system in an enterprise. In the following project phase business processes that are suitable for workflow management technology were identified. Project 5 was carried out by an insurance company to evaluate workflow management technology with a proto-

[1] The case study was conducted within the cooperative project MOVE [Herrmann et al. 1998] which is funded by the German ministry of education, science, research and technology (BMBF).

typical application. During the development of the prototype, severe runtime problems were identified. Finally, the company decided not to use a workflow management system for the development of the application. Project 6 focused on the introduction of a SAP R/3 application in an optical engineering enterprise. Several of the R/3-supported business processes will be performed using a workflow management system in the next years.
By examining the different development processes and the problems encountered, we are able to identify two classes of relationships: The first class combines those cases, where the problem can directly be shown by the existence or by the causal order of development activities (Problems 1 to 3, see below). The second class consists of cases, in which specific problems occurred during one particular activity (Problems 4 to 6). This distinction is important for the treatment of the problems by the reference development process model, as will be discussed below.

> *Problem 1*: The organizational and technical perspectives of the workflow schemas have often been worked out independently.

Organizational and technical perspectives depend on each other strongly, because there are technical constraints (like integration of legacy systems) which have strong influence on the design of organizational structures. An important flavour of this problem is the modularity of legacy applications. Often these applications have a much coarser granularity than required by the workflow application. These properties of existing information systems have to be taken into account in an early project stage. We remark that in one of the examined workflow projects, Problem 1 required a complete redesign of the organizational model, which caused a considerable delay in the project.

> *Problem 2*: In most cases, the selection of a workflow management system was done in a very early project state.

The workflow projects examined spent different amounts of time and cost in selecting a workflow management system. Interesting enough, system selection was among the earliest phases in the majority of the projects. In most projects, the early selection has been identified as one of the main source of problems, since the selected workflow management system could not support the specific requirements needed in the respective project. When the deficiency of the selected system was detected in a later state (often only during implementation phases), work-arounds had to be developed in order to fulfil the needs required by the application.

> *Problem 3*: The development process has been done without prototyping.

Only in one project, a prototype of the target application was developed. In most cases, prototyping was either not considered necessary for developing the workflow application or it was omitted due to project delays. It turned out, however, that prototyping is a very helpful activity in building workflow applications. The main reasons are as follows: Firstly, the organizational requirements of the business process can be validated in prototypes by the users of the system. It turned out that system usability and front-end design are important factors for the acceptance of the new technology by the workflow participants. Secondly, technical restrictions can be tested in an early project stage, which can save considerable resources in later project stages.

> *Problem 4*: An automatic transfer of business process models into workflow schemas proved to be unsuitable.

If business process modelling and workflow modelling were carried out with different tools, an automatic transfer of the business models into workflow schemas led to unacceptable results. We believe that a fully automatic transformation of business process models into workflow schemas is not feasible since they focus different aspects. In particular, business process modelling treats in detail the demands of the application from an application-oriented, i.e., from a business point of view, whereas workflow modelling focuses on the technological aspects of the application process and its organizational and technical environment. As a result, these domains are typically covered by different people using different terminology, i.e., business terminology versus information systems terminology.

> *Problem 5*: The integration of legacy systems was a critical factor for the success of workflow projects.

In all case studies, the integration of complex legacy systems was necessary. In none of the examined projects only simple applications like office systems had to be integrated. Besides, in all cases application integration was considered to be a critical success factor, since a re-implementation of legacy applications was not an option.

Problem 6: Severe performance problems could be identified during the field test phase.

During field test, every company of our survey had considerable problems regarding the performance of the workflow management application, if the application had to cope with a large number of users and workflow cases. In one case the application was lacking reliability, too. Although the integration of the legacy systems could be identified as one cause for these weaknesses the workflow management systems to a large extent were responsible for the technical problems.

3 Development Methodology

To clearly organize the phases and activities involving the development of workflow applications, this section presents a development methodology. We structure development processes by introducing the notion of a phase. A phase defines a time interval during which particular activities are performed.

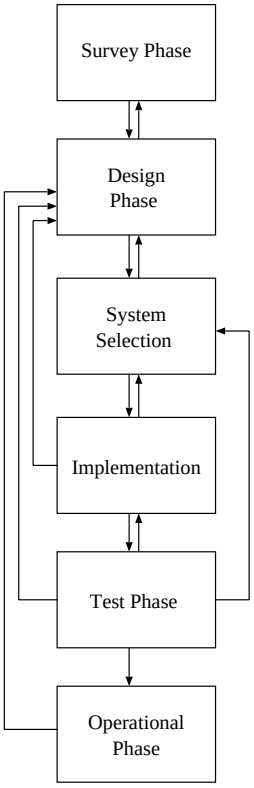

Figure 1: Development Methodology for WADP.

Typically, phases consist of related sub-phases or activities, which are carried out by a group of persons, using a set of input documents and developing a set of output documents. We stress that our understanding of a phase requires creative work performed by people and, thus, cannot be performed automatically [Holten et al. 1997]. Rather than presenting a formal method for describing development models, we use a rather informal notation, in which phases are represented by boxes, and informational and/or causal constraints are described by directed edges. Despite of being rather informal, the development methodology hints workflow project planners and managers to plan and conduct workflow development projects. The overall WADP development methodology is shown in Figure 1.

The development methodology starts with a Survey phase. In this phase, the goals of the project are defined, the project team is established, and initial information on the application environment is gathered. The project managers then decide which business processes will be selected. The main result of the Survey phase is a reviewed as-is business process model. The Design phase is next, in which the developed model is analysed and optimised to reflect the overall goals of the business, specified as a to-be business process model. (We remark that while business process re-engineering techniques are outside the scope of this paper, the development methodology can be enhanced such that these techniques are conducted within the development process.) Based on the as-is business process model, the project management decides whether workflow technology is adequate to support the requirements of the business process under investigation. If so, a suitable workflow management system is selected based on the requirements specified in the to-be business process model (System Selection), and the Implementation phase starts. The Test phase is next, which includes lab test and field test, as refined below. If the tests are successful, the Operational phase is reached.

We remark that the sequential processing of the phases represents an ideal situation, which most likely will not be appropriate in most workflow projects. To capture typical exceptions in the development process, we introduce additional edges, e.g., we permit certain phases or sub-phases to be re-performed during the development process. Defining and controlling the conditions under which development phases can be iterated is an important task of the project management, and it can be assisted by the WADP development methodology. We denote the property to step back in previously conducted phases as *evolutionary*, since development steps may iterate, incrementally improving the artifacts, for instance

business process models and workflow schemas. In doing so, a high degree of flexibility in developing workflow applications is provided. By defining possible iteration structures, the development methodology helps in ruling out jumps that are not meaningful. We mention that the evolutionary structure is present both *within* phases and *between* phases. As will be discussed in the remainder of this section, we define potential back jumps between sub-phases of different phases, e.g., a back jump from the Test phase to the System Selection Phase.

3.1 Survey Phase

The overall goals of the Survey phase are twofold. First, initial information on the domain is gathered to decide which business processes should be supported. The second goal of this phase is to develop a reviewed as-is business process model of the selected processes which contains both organizational and technical information (Fig. 2). Technical issues should also be taken into account in this early phase in order to identify possible restrictions due to limitations of the information systems to be integrated. In particular, legacy systems may pose specific requirements for tool integration. The Survey phase starts with an initial survey of the business process on an abstract level in order to get an overview of the process and the roles and departments involved. Besides, the team set-up for the Survey phase is done based on this information by identifying the persons to participate in the detailed survey. For example, this first activity can be carried out in an initial meeting with the project management.

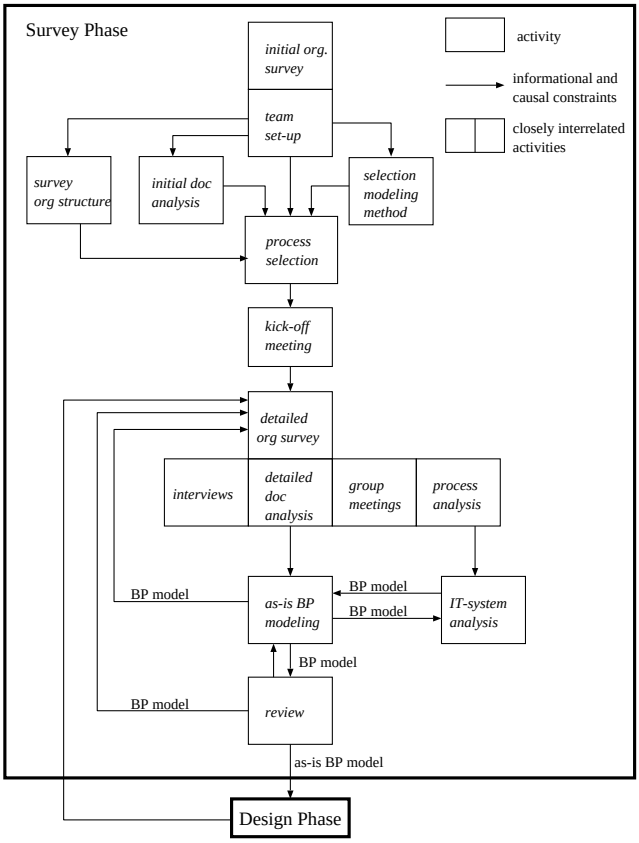

Figure 2: Survey Phase.

The next activities comprise a closer look at both the organizational structure of the company and the documents. This information is helpful for the process selection step, in which the relevant application processes are selected. In addition, this information is useful for the preparation of the survey team kick-off meeting. In this meeting, the overall goals of the project, the characteristics of the approach used, the processes to support, and the following activities are presented to the team members in detail. We stress that a strong participation of the employees involved is a key factor for the quality of the business model and, eventually, for the success of the project.

After the modelling method for the business process model is selected, the main activity of the Survey phase, the detailed organizational survey, is carried out. There are several options to obtain the relevant information in this sub-phase. (Adjacent boxes reflect a strong binding; typically the activities are executed concurrently, the persons collaborate closely and join intermediate results.) Interviews with survey team members are a costly but effective method to get detailed knowledge on certain activities within the business process. We stress that a detailed analysis of the documents is suitable in most cases. The detailed survey yields an initial version of the as-is business process model. If information is missing or ambiguous then the corresponding parts of the detailed organizational survey activity have to be repeated. In any case, the technical infrastructure of the company is analysed. The business process model is then extended with these aspects.

When a complete version of the as-is business process model is created, a review meeting with the entire survey team is carried out. The process model is presented to the team and discussed with the team in order to eliminate potential inconsistencies. Either these inconsistencies can be clarified in the meeting or the survey process iterates, and a new version of the process model is developed after another organizational survey activity. The new process model is again discussed in a review workshop. If all team members agree on the as-is business process model, the Survey phase is completed.

3.2 Design Phase

As we have mentioned before, the Design phase aims at analysing and optimising the as-is business process model. For that reason, this model serves as an input for this phase. The first set of activities deal with organizational and technical modelling of the so called to-be business process model, which represents the optimised business process which will be supported by the new application (Fig. 3). The organizational part can be subdivided into three sub-activities: process modelling, organizational structure modelling and data modelling.

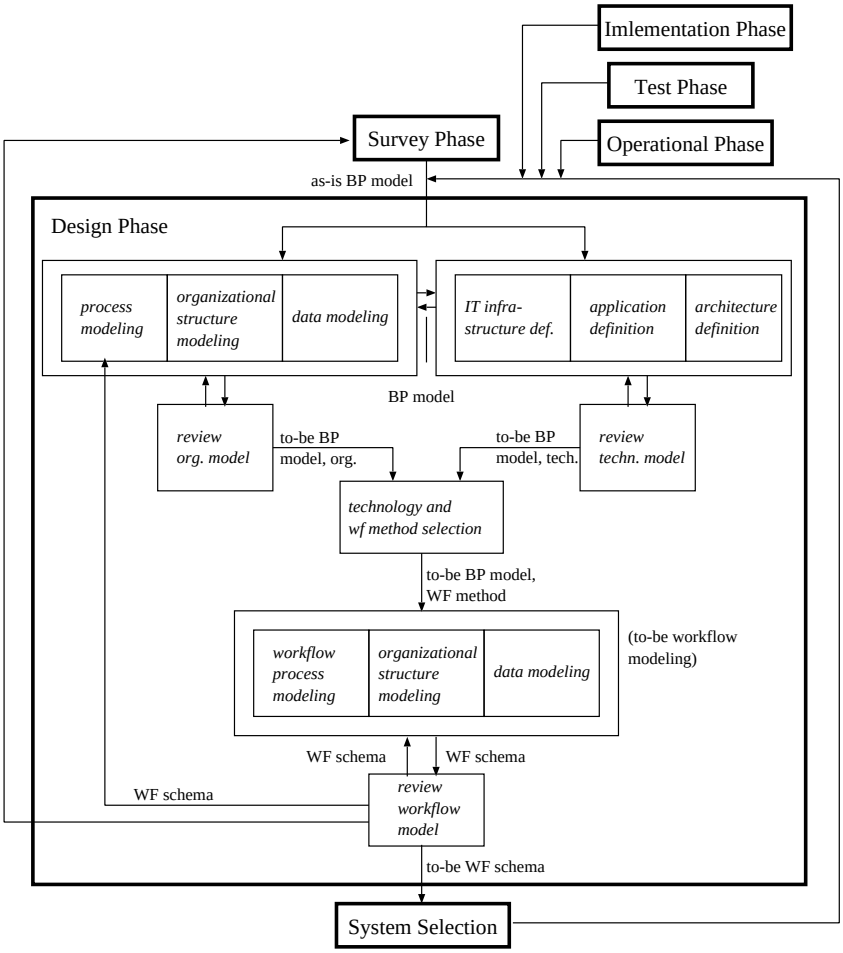

Figure 3: Design Phase.

Besides organizational properties, technical features like the infrastructure, applications and the architecture should be reflected in the to-be business process model. Organizational and technical to-be-modelling should be carried out in an iterative way, so that the strong dependencies between technical and organizational perspectives can be taken into account. At this point, fundamental knowledge on the business process is available. Using this knowledge on the process and on the organizational and technical environment in which the business process is performed, the team decides if workflow is an adequate technology to support the process. This is done in the technology / workflow method selection box. If so, an appropriate workflow method is selected, and the application development process continues as described in the development methodology. If, however, the project management decides that workflow is not adequate then the information gathered so far can be used as input for traditional software development.

A second set of activities during this phase are combined into to-be workflow modelling. We have already described the distinction between business process models and workflow schemas. The to-be

workflow modelling activity is subdivided into workflow process modelling, organizational modelling and data modelling. The output of this activity is a workflow schema which reflects the contents of the to-be business process model, enhanced by workflow-specific features. Since the workflow management system is not yet selected in this phase, a method for building the workflow schema must be chosen beforehand. An automatic transfer of business models into workflow schemas is not suitable in most cases [Holten et al. 1997], so appropriate resources should be provided for the to-be workflow modelling activity.

After the workflow modelling step has brought out its product (i.e., the workflow schema), a review activity can be carried out. Changes or new requirements may concern the business process model or the workflow schema, making it necessary that both business process modelling and workflow modelling can follow this review. The review activity may show that not enough information was gathered in the Survey phase. In this case, the WADP may re-perform parts of the Survey phase; in particular, the detailed organizational survey activity can be entered again to get the missing information, as shown in Figure 2.

3.3 System Selection and Implementation Phases

During the Design phase, the to-be business process model is developed. The main purpose of the System Selection phase is selecting a workflow management system, which is appropriate for the workflow application under development (Fig. 4).

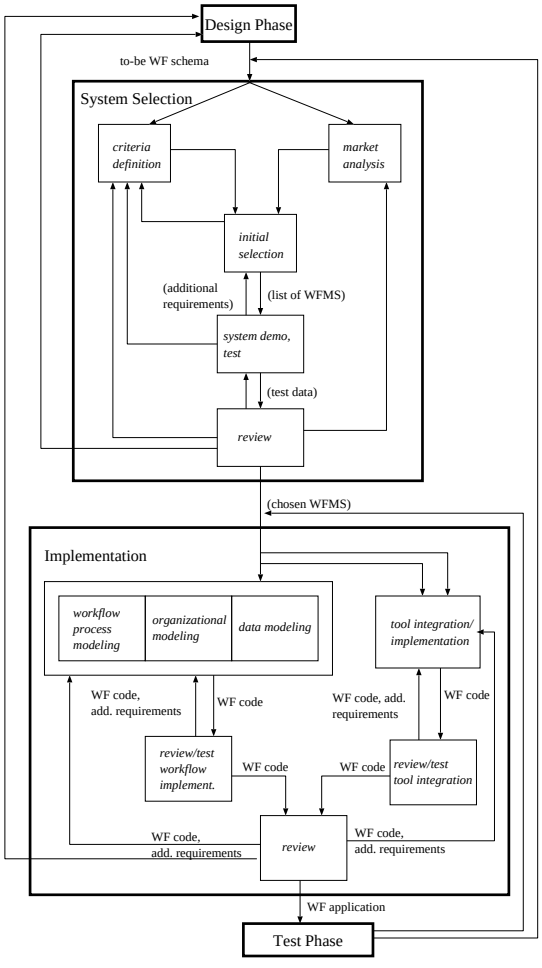

Figure 4: System Selection and Implementation.

As was discussed in Section 2, one of the main reasons for failing workflow projects is due to selecting an inadequate workflow management system. Among the potential reasons for this situation is selecting the system too early, since little or no information on the business process may be available by that time. Consequently, it is impossible to choose a system according to the specific needs of the workflow application. This point is important for the success of workflow projects, since the workflow management systems commercially available today differ considerably with respect to their functionality. The selection process starts with defining criteria for selecting an appropriate workflow management system based on the business process model as specified in the Design phase. Obviously, there is a myriad of criteria to select a suitable workflow management system, some of which are discussed now. The following set of criteria are relevant in the System Selection phase.

Integration criteria specify application and data integration aspects. In particular, the data structures and types of application systems which can be integrated in the workflow application are taken into account. We remark that these are important criteria, since the success of a workflow project may rely on the integration of existing, domain-specific ap-

plications, which typically have been developed independently from workflow applications. Interaction criteria deal with the question whether the user interface of the workflow management system is adequate for the users and the tasks to be supported. In particular, can it be customised to the specific needs of the application? Does the workflow client application have adequate notification mechanisms, like push- (the system actively notifies the client) and pull-communication (the client retrieves next workflow activities from the system)? Development criteria include the expressiveness of the workflow language underlying the workflow modelling tool, e.g., is it possible to express control flow, data flow and alternative execution paths, and other, application-specific properties? In addition, are there powerful simulation and test facilities present? Does it support flexible support for maintenance procedures and security and integrity constraints that are required by the application? Run-time criteria deal with the question whether the system provides adequate functionality for the end-user as well as modelling and monitoring functionality for process designers and process managers. In addition, is the workflow system able to process the load expected for the application, i.e., does the system scale? Finally, general criteria include questions whether the system is available for the platform that is already installed in the organization as well as issues related to the reputation and product strategy of the vendor and reference installations.
Based on these criteria, using market analysis data, an initial set of appropriate systems can be defined. However, if the systems available do not meet the criteria (or the systems cannot be used in the particular setting) then the selection criteria have to be re-defined. When a system is found that satisfies the criteria, it is tested against the requirements of the application. We stress that this activity may also lead to the re-definition of the criteria.
When the system tests are successful then a review meeting is carried out in which the final decision on the system to be used is taken. If the key requirements of the application are available before the Design phase is completed, the System Selection phase can start before business modelling is completed. This usually saves considerable amounts of time, especially if the systems to be tested require time to get hold of, to install, and to test. The Implementation phase is based on the to-be workflow schema and the workflow management system selected. Broadly speaking, this phase contains two major activities, one of which deals with the implementation of the workflow schema according to the formalisms and rules provided by the selected system. As is shown in Figure 4, this activity deals with specifying process models, data models and organizational models. The second activity in this phase is concerned with tool integration, i.e., the integration of external applications as specified in the workflow schema is performed. Depending on the support provided by the selected system, this activity may involve considerable amount of coding and extensive testing. In case of problems, the respective activities are re-performed. This process continues until the workflow implementation and the tool integration meet the requirements imposed by the to-be workflow schema. Finally, a review combines the results from the two activities. As specified in the figure, this process may iterate. This phase results in a workflow application, which is tested extensively in the next phase, i.e., the Test phase.

3.4 Test Phase and Operational Phase

The Test phase comprises the two sub-phases Lab Simulation and Field Test. Overall goal of the Test phase is to obtain information about the technical stability and the organizational suitability of the workflow application (Fig. 5). The first task in the Lab Simulation defines the simulation goals. This task directly depends on the to-be workflow schema created in the Design phase. The second task defines the test scenario. The test scenario defines the business processes and workflows which shall be tested. This means that the amount of data and the relevant business tasks are defined and that time restrictions are also specified. Now, test routines have to be developed, and the lab simulation is conducted and its results are analysed. If simulation analysis indicates that further simulation goals are of interest, another iteration of this sub-phase is started. Redefinitions of the test scenario may also be necessary. Notice that the simulation results by themselves can indicate that a re-implementation of the to-be workflow model is required. In this case, the implemented workflow application is not suitable for the given business application. If on the other hand the lab simulation finishes successfully, a Field Test can start.
The Field Test is performed to show that the workflow application is able to handle real world situations, characterized by problems which (at least partially) cannot be planned or predicted beforehand. Therefore, the application is tested against real world conditions. After defining the goals of the Field Test, the business processes to be tested are selected. For each such process, a backup solution must be provided to cope with potential error situations. Meanwhile, the employees involved in the tested processes have

to be trained on the new workflow application. At this point, the new system and the backup system have to be installed in the target environment. When the training is completed and the backup solution is (tested extensively and) safe, the Field Test can be performed. After its completion, the test data generated will be analysed, which may even result in the definition of new test goals or which may show new requirements influencing the selection of critical processes. This process can iterate, such that the Field tests become increasingly accurate.

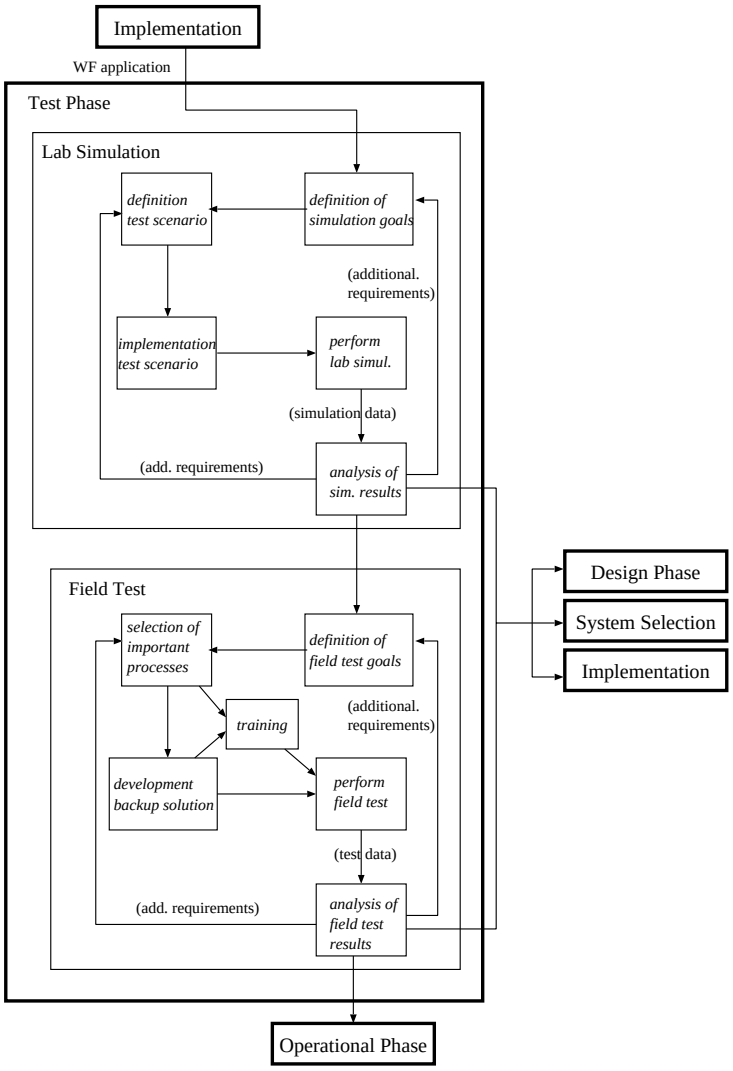

Figure 5: Test Phase.

We remark that the Field test may even show that the to-be business process or workflow schemas are not suited. In this case, the respective phases (Design, Implementation) are entered again; it may show that the workflow management system selected is not able to handle the current situation, in which case the System Selection phase is re-performed. Typically, a demo license of a workflow management system is used until the Operational phase (see below) begins, to limit cost if the Field Test results in a change of the selected system. The review activities in this phase may show severe problems, resulting in stepping back into the Design, System Selection, or Implementation phase, as shown in Figures 3 and 4.

The Operational phase comprises the sub-phases Installation and Run-Time as well as a set-up activity, in which the technical environment for the deployment of the workflow application is provided. The completion of this activity and the successful completion of the Field Test allow the start of the Installation phase. Without going into the details of this phase, the Installation sub-phase includes data migration and user training activities and the system deployment in the target setting, while the Run-time sub-phase is characterized by performing the daily business of the organization using the new workflow application, including gathering workflow execution data which can be used for continuous process improvement tasks.

4 Conclusions

We conclude by discussing how the development methodology helps in coping with the real-world problems mentioned above and by providing a brief summary.

To take care of the strong dependencies between the technical and organizational parts of the to-be models (Problem 1), the development methodology suggests that organizational and technical to-be modelling should be done collaboratively, and that the activities should exchange information. This is done in the Design phase, where the sub-phases, dealing with organizational and technical modelling are performed

in an integrated way, i.e., they are performed concurrently, and they exchange information. In addition, multiple iterations of the modelling phases may lead to a concise and integrated model which represents both aspects properly. System selection was often carried out in early project stages, resulting in Problem 2. In the proposed development methodology, system selection is based on the to-be business model, which is created during the Design phase. Hence, the specific properties of the workflow application are known when the workflow management system is selected. This information can be used to select a system which is capable of supporting this structure. In general, the functional requirements of the application are known when the system is being selected, which may lead to selecting more adequate systems and, eventually, to better workflow applications. The development of prototypes was identified as an important factor for the success of a workflow project (Problem 3). We did not define a separate prototyping phase in our model. Instead, prototyping is reflected by the evolutionary character of the overall process and by a dedicated field test phase. An automatic transfer of business process models into workflow schemas proved to be unsuitable in most cases (Problem 4). We stressed that the integration of legacy systems is a critical factor in workflow projects (Problem 5). For this reason, the Survey phase contains activities in which the characteristics of legacy applications are analysed in order to identify possible restrictions concerning the integration aspect. Besides, we suggest the definition of corresponding test scenarios in the Test phase. Many of the workflow management systems available are lacking performance and reliability if they have to cope with a large number of users and workflow cases (Problem 6). Our development methodology helps in dealing with this issue by providing elaborated System Selection and Test phases. We stress that performance and reliability should always be a key factor when conducting the different lab simulations in the Test phase.

To wrap up, in this paper we investigate workflow application development processes. By modelling and analysing workflow application development processes, the understanding of these processes can be enhanced and, finally, workflow application development can be improved. While the development methodology presented in this paper is designed to avoid a number of problems related to workflow projects, not all potential problems are solved by it automatically; in workflow projects, there is no substitution for knowledgeable project managers, skilled developers, and efficient users. However, given that "Models are not right or wrong, they are more or less useful" [Fowler 1997], we believe that our development methodology is indeed useful and can assist workflow project teams in developing more useful, more reliable, and better workflow applications.

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