

A Reference Model for 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 application development projects, this paper presents a reference model for workflow application development processes, which guides project managers and developers through the complex structure of these processes, with the aim of developing more adequate, usable, and reliable workflow applications.

KEYWORDS

workflow application development processes, reference modeling, design methodology

1 INTRODUCTION

Workflow management systems aim at the controlled execution of complex application processes in distributed and heterogeneous environments [7, 14, 18]. These systems are already and will continue to severely influence and shape the structure of information systems in business and non-business environments [19]. While software development processes have been investigated for some time now [2], the specific properties of workflow application development processes (WADP) received little attention so far. This paper tries to remedy this situation by analyzing problems encountered during the conduction of real-world workflow projects and by formalising the experiences drawn as a reference model for workflow application development processes, which can be customised towards the needs of particular workflow projects. While the general structure of the reference model is based on techniques known from software engineering process models (e.g. as described in [2]), the specific properties of workflow application and their implications to development processes of workflow applications are well taken care of.

The remainder of this paper is organized as follows: Section 2 collects the preliminaries on workflow management, and it discusses related work. Section 3 briefly discusses real-world workflow projects, and it shows a set of important problems, encountered during these projects. Section 4 proposes a reference model for workflow application development processes. Section 5 discusses how the reference model helps in dealing with issues discussed in Section 3. Finally, Section 6 shows how the reference model can be tailored towards the requirements of particular types of workflow applications.

2 PRELIMINARIES

This section collects the preliminaries on workflow management, on workflow application development processes and on reference modeling, needed throughout the remainder of this paper, and it discusses related work.

2.1 Workflow Modeling and Workflow Applications

Workflow management aims at modeling and controlling the execution of complex application processes in a variety of domains, including the traditional business domain [18, 7, 14] and the natural sciences [13, 29]. Workflow models are representations of application processes and of the technical and organisational environment of their execution, to be used by workflow management systems for controlling the execution of workflows. 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. We stress that in order to develop adequate workflow applications, these persons, their skills and expertises also have to be taken into account during the development of the workflow application. While workflow application development processes differ from one project to the next, the general procedure can be described as follows [12]:

The first phase of workflow application development processes deal 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 modeling, in which the information gathered is used to specify business process models. The main purpose of business process modeling is to provide a general and easy-to-read notation, which enables information system experts and domain experts to validate and optimise 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 modeling 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. In this phase, workflow languages are used [30]; finally the workflow application is deployed in the target environment, and the operational phase starts.

2.2 Related Work

Surprisingly, little work has been published on workflow application development processes so far. Kwan and Balasubramanian present a “Workflow-aware Information System Development Methodology” [16], which presents a rather high-level description of workflow application development processes. While that paper presents an interesting approach to the subject, there are some deficiencies which we try to overcome. First, the paper neglects some major issues, e.g., it regards a workflow management system as given,

and a system selection depending on survey data is not part of the development process. In addition, a customisation of the development process depending on the needs of the workflow project is also not discussed in that contribution. A general approach for the development of workflow applications is discussed in [15]; that contribution concentrates on the phases of project planning and justification, operations review and analysis, market survey and product selection and user training and support. However, it does not present the internal structure and relationships between the phases in detail. The well known workflow reference model developed by the Workflow Management Coalition [17] defines required components for the development and usage of workflow applications. However, it does not define reference processes for the development of workflow applications.

Besides software development processes, work in the area of reference modeling is also related to our approach. Reference models in general serve as means for the orientation of modellers and developers by providing a point of reference in the quest for adequate solutions [27]. In contrast to individualised solutions, reference models represent a class of application cases; hence, they intend to serve as patterns for solutions of specific real-world problems. Process models for the customisation and implementation of standardised software systems like SAP R/3 [21] or process models for business process re-engineering [11] also fall into this category. Users of reference models are interested in the reduction of project cost achieved especially through faster development as an empirical study shows [27]. This goal applies to the development of a reference model for workflow development processes in this paper as well; it can be used as a guideline for planning and conducting workflow application development processes. Examples of reference process models are the well known models of software engineering processes (e.g., waterfall model [2], fountain model [8], prototyping approach [3, 22]). While the reference model presented in this paper belongs to this class of reference process models, we focus specifically on the issues encountered during workflow projects. As will be explained in the remainder of this paper, workflow projects exhibit significant differences with respect to traditional software engineering projects. The specific properties of workflow applications – as will be elaborated in the text – lead to the fact that traditional software engineering process models (as described in, e.g., [2]) do not support well the specific requirements of workflow application development processes and, hence, are not suitable for most workflow projects.

3 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:

3.1 Organization of Case Studies

The studies are organized in three steps: survey, modeling, 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

¹The case study was conducted within the cooperative project MOVE [9, 20] which is funded by the German ministry of education, science, research and technology (BMBF).

out?”, “What kinds of problems occurred, and how did you manage them?” and “In a follow-up 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 modeling step. Its purpose is to compare the different development processes, using a “development process model” for each case. In order to ensure comparability of results, a common meta model is used [10, 12], which contains the meta types phase, person/role, document/product, and language. Using this meta model and the reference instances of the meta types, the development process models for the cases are generated. 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. Further details of the case study method can be found in [10].

3.2 Characterisation of Analyzed Workflow Projects

As discussed above, the WADP reference model is based on lessons learned from the conduction of a number of industry workflow projects. The following list sketches key properties of these projects; more details can be found in [10].

- Project 1 was carried out by a telecommunications service provider. The project started in 1994 and 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 is still (1998) in the field test phase. The main issues encountered during this project are reviewed below.
- Project 2: In 1994, a logistics services company initiated a workflow project aiming on the improvement of customer service processes. The 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 using workflow management technology.
- In Project 3, another logistics enterprise planned a workflow management application for an order processing business process. The project is still in progress, delays were 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 the enterprise. In the following project phase business processes that are suitable for workflow management technology were identified. At present, the project is still in the design phase.
- Project 5 was carried out by an insurance company in 1995 to evaluate workflow management technology with a prototypical application. During the development of the prototype, various severe 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 starting in 1995. Several of the R/3-supported business processes will be performed using a workflow management system in the next years.

3.3 Problems Encountered

The main case study results are outlined now. When examining the different development process models 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 organisational and technical aspects of the workflow model have often been worked out independently.

Organizational and technical aspects depend on each other strongly, because there are technical constraints (like integration of legacy systems) which have strong influence on the design of organisational structures. On the other hand, the technical solutions should always be derived from organisational requirements. For this reason, the organisational and technical aspects should be designed closely connected in an iterative way. In one of the examined workflow projects, this problem required a complete redesign of the organisational model.

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 system. Interesting enough, system selection was among the earliest phases in the majority of the projects. Two of the examined projects set up an extensive selection process, whereas some other projects used an existing working relationship to a specific vendor or other non-technical arguments for their decision. In most projects, the early selection has been identified as one of the main problems, since the selected workflow management system could not support the specific requirements needed in the project, and adaptations in later project states caused considerable overhead.

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

Only in one case a prototype of the target application was developed. It turned out that prototyping is a very helpful step in building workflow applications. On the one hand the organisational requirements of the business process can be validated by future users. On the other hand, technical restrictions can be tested in an early project stage, which is very important when building workflow applications (cf. Problem 6). In most projects, prototyping is considered to be an indispensable activity now.

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

If business process modeling and workflow modeling were carried out with different tools, an automatic transfer of the business models into workflow models led to unacceptable results. We believe that a fully automatic transformation of business process models into workflow models is not feasible since they focus different aspects. As a result, the expenditure on subsequent modifications of the workflow model turned out as very high. However, the manual transfer of business process into workflow models proved to be difficult, too. In one case certain relevant aspects of the business process model could not be translated into the workflow model due to limitations of the expressive power of the workflow management system selected.

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

In all case studies of our survey the integration of legacy systems was a critical success factor of the project. Considerable efforts were necessary to integrate the different systems into the workflow application. One of the main issues in this context was the development of interfaces between the workflow management system and the applications. In some cases where the characteristics of the legacy systems were identified late in the project, costly modifications were required.

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.

4 REFERENCE MODEL FOR WORKFLOW APPLICATION DEVELOPMENT PROCESSES

This section presents the reference model for workflow application development processes. We structure development processes by introducing the notion of a phase. A phase defines a time interval during which particular activities are performed. 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. In the remainder of this section we provide a high-level description of the WADP reference model, focusing on its evolutionary character, and we show the internal structure of the phases and the relationships between phases in some detail.

4.1 Overview and Evolutionary Approach

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 reference model hints workflow project planners and managers to plan and conduct workflow development projects. The overall WADP reference model is shown in Figure 1.

The first phase of our reference model is the Survey Phase. In this phase, first the goals of the project are defined, the project team is established, and initial information on the application is gathered. The project managers then decide which business processes will be selected for the development process. 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 analyzed 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 reference model can be enhanced such that these techniques are conducted within the model.) Based on this model, the project management decides whether workflow technology is adequate to support the requirements of the particular business process. 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.

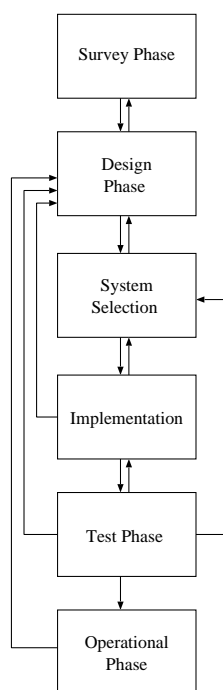


Figure 1: Reference Model for WADP.

We remark that the sequential processing of the phases as described above represents an ideal situation, which most likely will not be appropriate in most workflow development processes. To capture typical exceptions in the development process, we introduce additional edges, e.g., we allow 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 property of the WADP reference model. We denote this property as *evolutionary*, since development steps may iterate, incrementally improving the artifacts (e.g., business process models, workflow models) during the workflow application development process. By doing so, a high degree of flexibility in developing workflow applications is provided. By defining possible iteration structures, the model helps in ruling out jumps that are not meaningful. We mention that the evolutionary structure is present within all phases and also between phases. As will be discussed in the remainder of this section, we define potential back jumps between sub-phases of one phase and sub-phases of different phases.

The phases of the reference model consider the three dimensions of the Requirements Engineering Framework presented in [24, 25]. This framework presents the dimensions specification, representation, and agreement. The specification dimension should be as complete as possible with respect to the development phase under consideration. For example, the as-is business model must give a complete survey of the organisational and technical aspects of the business process, the new workflow application is intended to support, as will be discussed shortly. The to-be specification as a set of related documents becomes increasingly concrete in the following phases, especially in the Design Phase. The representation of the documents under development as second dimension of the framework becomes more and more formal by approaching the Implementation Phase. The Design, Survey and Implementation phases in our reference model are characterized by final review activities intended to secure the agreement of the development team to the created solution. Agreement is the third dimension of the

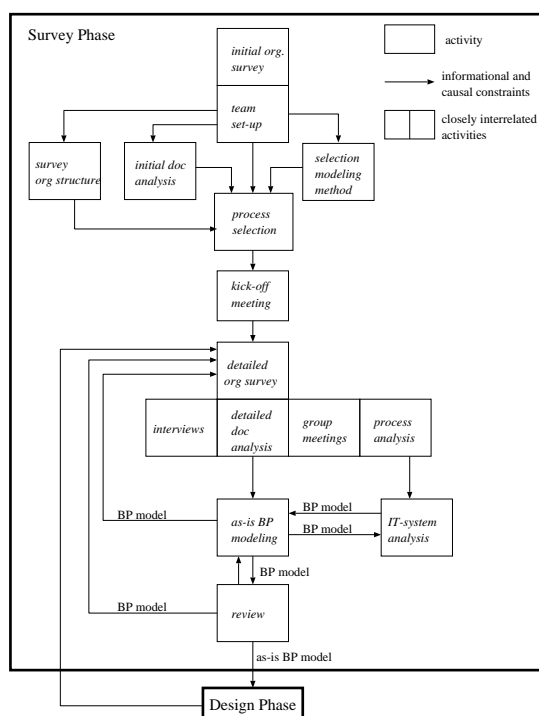


Figure 2: Survey Phase.

Requirements Engineering Framework. The development process itself can be described as an iterated conduction of activities and phases restricted by the arrows in our diagrams which define allowed development paths.

4.2 Survey Phase

The overall goals of the Survey Phase are twofold. First, we gather initial information on the domain 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 organisational 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.

The next activities comprise a closer look at both the organisational 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 modeling method for the business process model is selected, the main activity of the Survey Phase, the detailed organisational 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 organisational survey activity have to be repeated. In any case, technical infrastructure of the company are analyzed. The business process model is then extended to this 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 in the model. 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 organisational 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 finished.

4.3 Design Phase

As we have mentioned before, the Design Phase aims at analyzing 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 organisational and technical modeling of the so called to-be business process model, which represents the optimised business process which will be supported with the new application (Fig. 3). The organisational part can be subdivided into three sub-activities: process modeling, organisational structure modeling and

data modeling. Beside organisational 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-modeling should be carried out in an iterative way, so that the strong dependencies between technical and organisational aspects 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 organisational 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 reference model. If 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 modeling. We have already described the distinction between business process models and workflow models in Section 2. The to-be workflow modeling activity is subdivided into workflow process modeling, organisational modeling and data modeling. The output of this activity is a workflow model which reflects the contents of the to-be business process model, enhanced by technical features. Since the workflow management system is not yet selected in this phase, a method for building the workflow model must be chosen beforehand. An automatic transfer of business models into workflow models is not suitable in most cases [12], so appropriate resources should be provided for the to-be workflow modeling activity.

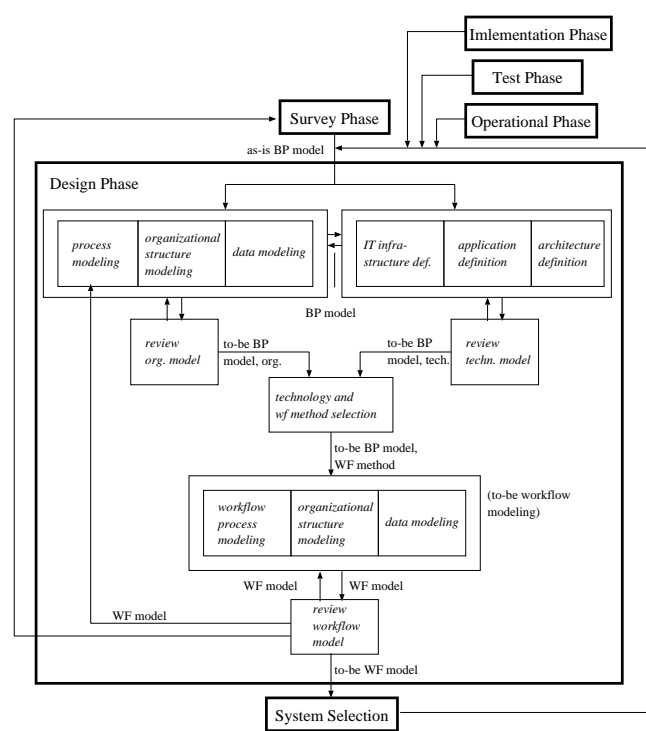


Figure 3: Design Phase.

After the workflow modeling step has brought out its product (i.e., the workflow model), a review activity can be carried out. Changes or new requirements may concern the business process model or the workflow model, making it necessary that both business process modeling and workflow modeling 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 organisational survey activity is entered again to get the missing information, as shown in Figure 2.

4.4 System Selection and Implementation Phases

During the Design Phase, the to-be business process model is identified. 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). As was discussed in Section 3, 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. Based on studies conducted in Germany [4, 5] and criteria defined in [15], the following classification of criteria is relevant in the System Selection Phase:

- *Integration criteria:* 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 applications, which typically have been developed independently from workflow applications.
- *Interaction criteria:* Is the user interface of the workflow management system 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). Finally, is the amount of training required for users to work with the new system appropriate? Does the system provide flexibility in executing workflows, e.g., does it support dynamic change of workflow models while workflows run [31]?
- *Development criteria:* These criteria include the expressiveness of the workflow language underlying the workflow modeling 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:* Does the system provide adequate functionality for the end-user as well as modeling and monitoring functionality for the process designer and for the process manager. In addition, is the workflow system able to process the load expected for the application, i.e., does the system scale? Providing distributed workflow control in object oriented environments, which is discussed with the specification of the OMG Workflow Facility [23], may help to solve scalability (and interoperability) issues. Does the system save intermediate workflow states in persistent storage, so that workflows which are interrupted can be recovered safely?
- *General criteria:* Is the system available for the platform that is already installed in the organization? These criteria include the reputation and product strategy of the vendor (will there be support for the produce in five years from now?) and reference installations.

Based on the criteria mentioned, 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 modeling 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 model as specified in the Design Phase and the workflow management system selected. Broadly speaking, this phase contains two major activities, one of which deals with the implementation of the workflow model according to the formalisms and rules provided by the

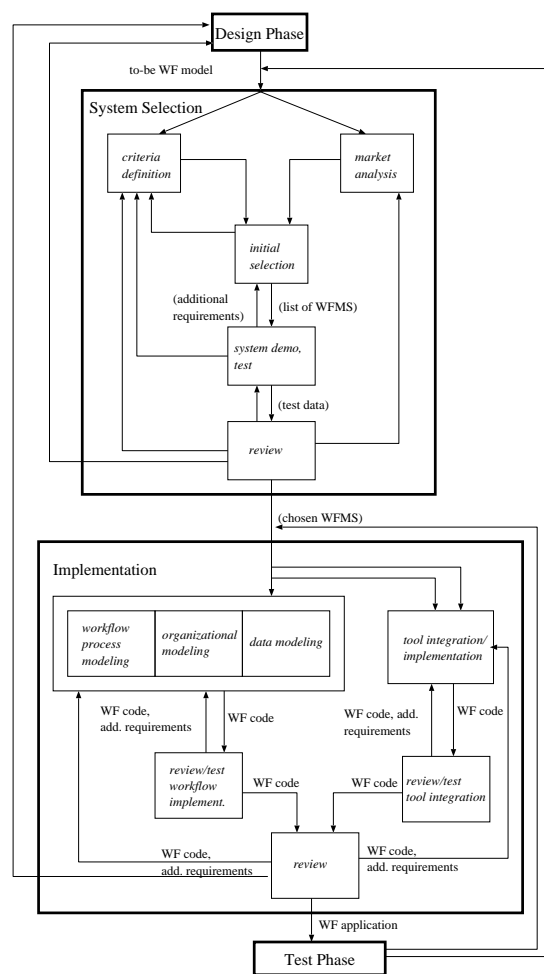


Figure 4: System Selection and Implementation.

selected system. As is shown in Figure 4, this activity deals with specifying process models, data models and organisational models. The second activity in this phase is concerned with tool integration, i.e., the integration of external applications as specified in the workflow model 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 model. 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 used in the Test Phase. However, the review may result in the decision to re-perform the Design Phase. In this case, the Design Phase is re-entered, as shown in Figure 3.

4.5 Test 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 organisational 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 model created in the Design Phase. The second task defines the test scenario. The

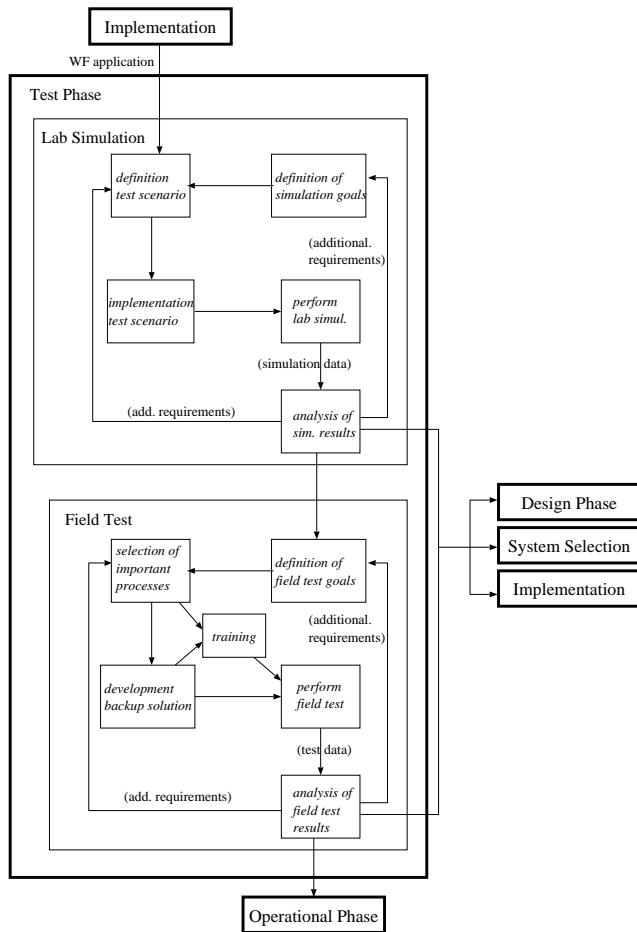


Figure 5: Test Phase.

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 analyzed. 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, which is discussed next.

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. If 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 analyzed, 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.

We remark that the field test may even show that the to-be business process or workflow models 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.

4.6 Operational Phase

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 (Fig. 6). The completion of this activity and the successful completion of the Field Test allow the start of the Installation Phase.

The Installation sub-phase includes data migration and user training activities and the system deployment in the target setting. User training involves educating employees on using the new workflow application. Data migration deals with relocating data from original systems into the new workflow application or in other systems, as required. This is a highly complex and important technical issue. If the training and the data migration are finished successfully, the new workflow application can be deployed in the enterprise.

The Run-time sub-phase is characterized by performing the daily business of the organization using the new workflow application. Workflows are monitored and execution data is gathered, which is important for the continuous improvement of the workflow application and the respective business processes. In particular, the performance monitoring produces data for the process controlling activity, which in turn produces information for a continuous process improvement task. The latter task also gets information from the operational business directly, mostly information of informal character. We remark that continuous process improvement is a complex activity, whose internal structure is not covered in this paper. However, the continuous process improvement activity may create suggestions to be used in the Design Phase, as shown in Figure 3.

5 CASE STUDIES REVISITED

In Section 3, a set of important problems of workflow projects were identified. Below we explain how the reference model presented in the previous section helps in coping with these problems.

As we pointed out earlier, there are strong dependencies between the technical and organisational parts of the to-be models (Problem 1). For this reason, the reference model suggests that organisational and technical to-be modeling should be done collaboratively, and that the activities should exchange information. In addition, multiple iterations of the modeling phases may lead to a concise and integrated model which represents both aspects properly. System selection was often carried out in early project stages (Problem 2). In the reference model the system selection is based on the to-be business model. Hence, the particularities of the workflow application are known when selecting a workflow management system. 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 finally, to better workflow applications. The development of prototypes was identified as an important factor for the success of a workflow project

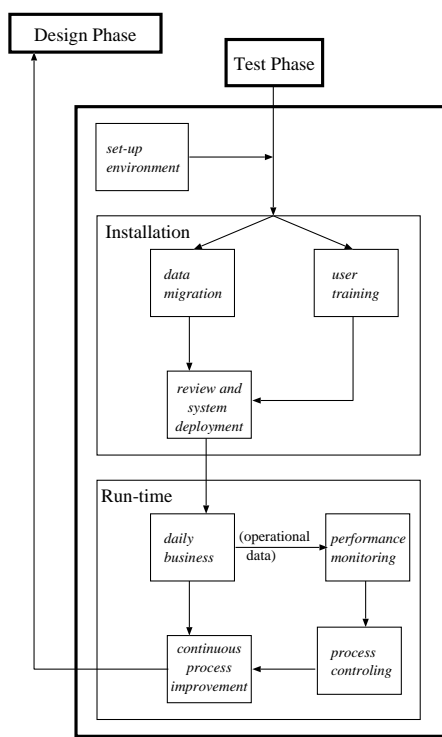


Figure 6: Operational Phase.

(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. We strongly recommend the development of prototypes, especially to identify technical restrictions and possible performance bottlenecks, for instance using iterations in the Design and Implementation Phases.

An automatic transfer of business process models into workflow models proved to be unsuitable in most cases (Problem 4). Although the workflow model is based on the to-be business process model in our reference model, we do not recommend an automatic translation of the corresponding modeling information. 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 analyzed 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 reference model 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.

6 CUSTOMISING THE REFERENCE MODEL

To demonstrate a sample customisation of the reference model, we propose a two dimensional framework defined by “workflow experience” and “problem complexity” (Figure 7). Problem complexity can be thought of as determined by mission criticality of the business process, the expected work-load, measured for example in the estimated number of cases, the number of users and

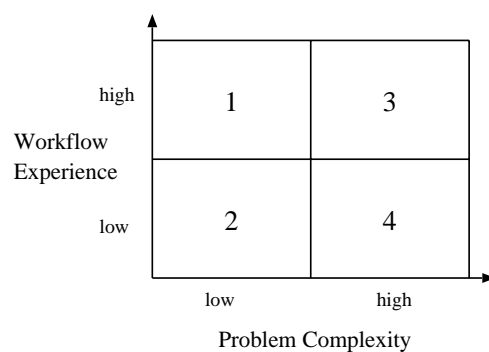


Figure 7: Workflow Development Dimensions.

the number of activities to be managed by the workflow management system. Workflow experience can be characterized as the experience of the involved persons (e.g., project managers, developers, system administrators, users) with workflow development and workflow applications. We remark that various other factors do play a role in problem complexity and workflow experience; however, the characterisation given suffices for the purpose of this paper.

In Figure 7, four types of workflow development situations can be distinguished. (1) Highly experienced team and low problem complexity: The problem can be characterized as standard problem with respect to the experience of the team. Typically, a workflow application of the same problem complexity is already operational in the enterprise. (2) Low experience and low problem complexity: This scenario characterises a typical first workflow project in a given enterprise, where the persons participating in the development of the workflow application have to be educated on the workflow paradigm and convinced about its usability. (3) Highly experienced team and high problem complexity: A fine challenge for a knowledgeable team. (4) Low experience and high problem complexity: A scenario better avoided. Based on these scenarios, the reference model can be customised in the following ways.

1. Because of the experience of the team, the information needed to select a suitable workflow management system may be gathered with less expenditure than in other cases. In some cases, the System Selection Phase of the reference model can be reduced to a validation activity, which analyses the suitability of the existing workflow management system for the project under consideration. This validation activity can become part of the Design Phase and should follow the to-be BP modeling activity.
2. The reference model should be used as specified in the reference model; major simplifications may not be suitable in most cases.
3. This scenario is in some way similar to scenario 1. But the success of the validation activity is much more unlikely since the problem complexity is high. Chances are that the already used workflow management system is not suited to cope with the requirements defined by the complex application scenario. In any case it is not advisable to cut out the Test Phase since the business processes under consideration are mission critical and/or considerable system load is expected.
4. This scenario indicates a disadvantageous situation, and the reference model should be followed in any step. Most activities will be of high expenditure. As an advice the team

should first gain some experience in a project classified as of lower complexity, i.e., to conduct a scenario 2 workflow project. The involvement of knowledgeable and experienced personnel is advisable.

7 DISCUSSION

In this paper we investigate workflow application development processes. We believe that a thorough study of these processes can lead to more timely workflow projects and more adequate, usable, and reliable workflow applications. While the reference model presented in this paper is designed to avoid a number of issues 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, the reference model presented assists managers of workflow projects in planning, organising, and conducting the complex process of workflow application development. By putting the focus on workflow application development processes, the understanding of these processes can be improved, which may finally lead to better and more usable workflow applications.

While this paper presents a reference model for workflow application development processes, it just sketches some ideas of how to customise the reference model towards the needs of specific workflow projects. Our model is a reference model since it proposes possible ways to develop a workflow application and thus helps in planning and managing workflow projects. Of course, to take care of the specific properties of workflow projects, an individual project plan is required for any project. The reference model presented in this paper gives hints how the project can (and should) be structured, i.e., the reference model needs to be customised for each workflow application development process. We remark that our reference model is a proposal, and real-world usages of the model may show its quality. However, since "Models are not right or wrong, they are more or less useful" [6], we believe that our reference model is indeed useful in planning and conducting workflow projects.

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