A Step Forward in the Theory and Practice of ICT Management Simulation

PROEFSCHRIFT

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Chapter 1

Simulation of ICT Management Processes: An Introduction

1.1 Introduction

Information and Communication Technology (ICT) is becoming more and more an inseparable part of modern society. ICT is growing and spreading with increasing speed and influences all aspects of our lives. Modern organizations are among those who are most affected by these developments. For many of them the quick adoption and utilization of ICT has become a question of survival. This, however, has created gaps in our knowledge with regard to the optimal way in which ICT should be managed. Therefore, both researchers and practitioners in the field of ICT put increasing efforts in creating models, approaches and tools which will allow for bridging these gaps.

This chapter lays the foundations of the present research project on the simulation of ICT management processes. It describes the background and motivation for the research, the problems addressed by the research, the research questions and objectives, as well as the methodology and approach used to achieve these objectives.

The chapter is structured as follows. Section 1.2 provides some background information about ICT and the challenges its management creates, as well as the most popular ICT management models and approaches. In section 1.3 a number of issues in the area of ICT management are presented, the approaches and tools used to cope with these issues, as well as their advantages and disadvantages are discussed, and some points for improvement are identified. Section 1.4 provides information about animated simulation and the advantages it offers for coping with the issues identified in the previous section. On this basis, in section 1.5 the problem area and the objectives of the research project are defined, and the main research question and its sub-questions are formulated. In section 1.6 the adopted research methodology is described, and the research approach implementing this methodology is presented. Finally, in section 1.7, the main points from the research background, objectives and organization are summarized, and an outline is given of the contents of the remaining chapters of the dissertation.

1.2 ICT and its management: a challenge to contemporary organizations

The following sections provide some general information about ICT and its management. They also highlight some of the most important characteristics of ICT and the challenges, faced by contemporary ICT managers. Several widely accepted and widely used approaches to the management of ICT are also discussed.

1.2.1 Information and Communication Technology

It is a generally acknowledged fact that Information and Communication Technology (ICT) is penetrating the modern world at an ever-increasing pace. All spheres of everyday life are becoming increasingly dependent on ICT and the possibilities it offers. ICT changes the way people work, the way people live, the way people think. Rapid technological advances in the field of information storage, processing and transportation create enormous opportunities for companies and organizations (Donovan, 1994), and are vital to creating competitive products and services (Turban et al., 2001). Personal computers play a greater and more important role in the households – from an exotic device 20 years ago, they are turning more and more into an "electronic brain", which carries out the exchange of voice, video and data information with the outside world, and even takes care of things like air-conditioning and security in the house. Global computer networks rapidly transmit enormous amounts of data all over the world, providing governments and institutions with information, which allows these to change the way they plan and conduct their policies. As Tapscott (1996) puts it, "businesses will be transformed, governments will be renewed, and individuals will be able to reinvent themselves – all with the help of information technology". ICT has become a strategic weapon.

1.2.2 ICT Management

With the increasing use of ICT in the modern world, ICT management is becoming more important and comprehensive. Having started in the sixties and seventies as a purely technical function, aimed at operating and supporting the implemented computer systems and mainframes, today ICT management comprises aspects like ICT strategy formulation, cost management, personnel management, quality management, service level management, software control and distribution, network management, user support (Looijen, 1998; CCTA, 1999; Hendricks and Carr, 2002). According to Looijen (1998), ICT management takes care that the implemented ICT functions according to the predefined requirements (e.g., types of services, availability, reliability, response time, security) and within the predefined constraints (e.g., cost, centralization/decentralization, personnel, standardization). It plays a vital role in the planning and achieving of the business goals of organizations (Sprague and McNurlin, 1993; Donovan, 1994; Turban, 2001), and its influence on the formulation and realization of corporate strategy is increasing (Lucas, 1997). This, together with the growing size and complexity of applications and technical infrastructure, results in a continuous increase in the complexity and volume of ICT management (Looijen, 2000), and changes the way in which this management is carried out (Gallivan, 1994). The size, diversity and sophistication of application software and hardware infrastructures used by contemporary organizations are increasing, the number of people involved in ICT management is rising, the dependencies and interrelationships among the different aspects of ICT management are becoming more complex, and the ICT budgets of organizations are growing.

As a result of this, the tasks of contemporary ICT managers are becoming more difficult and demanding. Change has become a given in their life (Manzoni and Angehrn, 1998) and they have to cope with a number of challenges, both technological and managerial, in the daily practice of ICT management (Applegate et al., 1999, Frenzel, 1996, Turban et al., 2001). Examples of the technological challenges are the rapid change and developments in technology and the integration of different technologies (Benamati et al., 1997), the growing size of hardware, applications and data, the compatibility and connectivity problems due to the diversity of ICT vendors, the specialization in increasingly narrow areas of expertise, the (in many cases critical) importance of the firm’s computer operations. The managerial challenges include finding and retaining skilled people in the conditions of scarcity of IT talent on the labour market, formulating service level agreements with the end users of the implemented ICT and supervising the realization of these agreements, managing the IT budget of the organization and aligning the IT strategy with the corporate strategy of the organization. All these factors make ICT management a very complex and challenging activity, which demands both technological expertise and management capabilities at a high level and involves a growing number of people, technical and financial resources.

With this in mind, it is clear that effective and efficient ICT management is necessary in order to make optimal use of and to obtain the best added value from the implemented ICT. Several approaches aimed at achieving this are presented in the next section.

1.2.3 Approaches to ICT Management

In order to assist the planning, implementation and daily execution of ICT management, a number of ICT management approaches have been developed which are used increasingly in the contemporary ICT management organizations. The purpose of these approaches is to impose a structure on the organization of ICT management, to define the tasks and the processes that have to be carried out, as well as to outline the dependencies and interrelationships that exist within the ICT management organization on the one hand, and between the ICT management organization and external clients and/or suppliers, on the other. Some of these approaches are outlined in the rest of this section.

One of the approaches to ICT management is the so-called MCM (Management, Control and Maintenance) approach developed by Looijen (Looijen, 1998). This is a task-oriented approach, which describes a framework for organizing the management of information systems, consisting of a collection of tasks that have to be carried out in order to achieve effective and efficient ICT management. Related tasks are grouped into task fields, which in their turn are grouped into task areas. Using the logo of Mintzberg (Mintzberg, 1993) the task areas are positioned on three different levels: operational, tactical and strategic level, and in three forms of management: functional, application and technical management. A detailed description of the task areas at the different levels and forms of management is provided, and the relationships with other task areas are explained. An important part of the approach is the so-called State Model, which describes the life cycle of an information system from its planning to its implementation, use and maintenance. The MCM approach provides a sound frame of reference with regard to the tasks that have to be carried out in ICT management, the interrelationships that exist among them, and the place in the ICT organization where they have to be carried out.

Another prominent approach to the organization of ICT management is ITIL (Information Technology Infrastructure Library) developed by the Central Computer and Telecommunications Agency (CCTA) in Great Britain (CCTA, 1990). This is a process-oriented approach, which describes a number of processes attempting to cover all aspects of ICT management. The processes are described in books with a standardized layout, starting from the planning and preparation for the processes, through their implementation, to their actual execution and control. The process content is described in terms of functions and activities that have to be carried out. The relationships of a process with other ITIL processes are also given. Similar processes are combined it the so-called sets. At present there are nine sets in ITIL, six of which focus on the delivery and support of ICT services and on the management of the ICT infrastructure, and three cover environmental issues in the production of ICT services. At present ITIL is a very popular approach and an increasing number of organizations are adopting it as their main "guideline" in organizing ICT management.

There are also a number of other approaches, developed by organizations and firms active in the field of ICT Management. Examples of these are the IT Services Management Reference Model (ITSMRM) developed by Hewlett-Packard, the IT Process Model (ITPM) developed by IBM, and the IIM (Information Infrastructure Management) model. However, the use of these models is mainly restricted to the organizations that developed them and to some of the organizations that use their services, and their importance for and contribution to the overall body of knowledge in the field if ICT management is limited.

More detailed information about the above-mentioned ICT management approaches, the models and ideas on which they are based, as well as on their relationships, advantages and disadvantages is provided in chapter 2 of this book. In the next section a number of issues are presented related to the implementation of these approaches in practice and the way in which the present research project addresses these issues is explained.

1.3 Research Project Background and Motivation

As explained in the previous sections, there are a number of challenges in the field of ICT management with which managers have to cope in order to manage the implemented ICT in an effective and efficient way. Various ICT management approaches have been developed to assist them in this task, some of which were mentioned in section 1.2.3. However, the application of these approaches in practice gives rise to a number of issues, some of which are presented in section 1.3.1, which have to be resolved in order to achieve a successful implementation. In order to resolve these issues, ICT managers make use of a large number of methodologies and tools, most of which come from the sphere of Business Process reengineering (BPR) and have some limitations with regard to the modeling and visualization of the dynamics of ICT management processes. The analysis of these limitations in section 1.3.2 leads to the formulation of a number of points for improvement in section 1.3.3, which form the basis of the motivation for the research project.

1.3.1 Research Background

The research presented in this thesis was carried as part of the research program on ICT management simulation of the chair *Information Strategy and Management of Information Systems* of the Department of Information Systems Management, Faculty of Information Technology and Systems of the Technical University Delft. The research program focused on the use of simulation for modeling ICT management processes in order to gain insight into their functioning, characteristics and interrelationships.

A number of publications were made in the course of the research program (see, e.g., de Jong, 1998b, de Jong and Looijen, 1999 and de Jong, 2000) and an ICT management simulator was built (fig. 1.1). The simulator offered an opportunity to study the changes in different characteristics of ICT management processes by changing process parameters (e.g., queue length and processing speed) in the model. It also calculated a "score" for the processes based on the chosen parameter values. The simulator was used by students for carrying out assignments as part of the course on ICT management.

The results of the research program and the ICT management simulator were presented at different conferences, workshops and seminars with companies from The Netherlands. One of the conclusions made was that animated simulation could be a valuable tool for gaining insight into the dynamic behavior and interrelationships of ICT management processes, as well for their reengineering. Another conclusion was that there was no company which used animated simulation for modeling their ICT management processes due to a large extent to the unawareness of the benefits it offers, as well as to the lack of expertise necessary to build such a model.

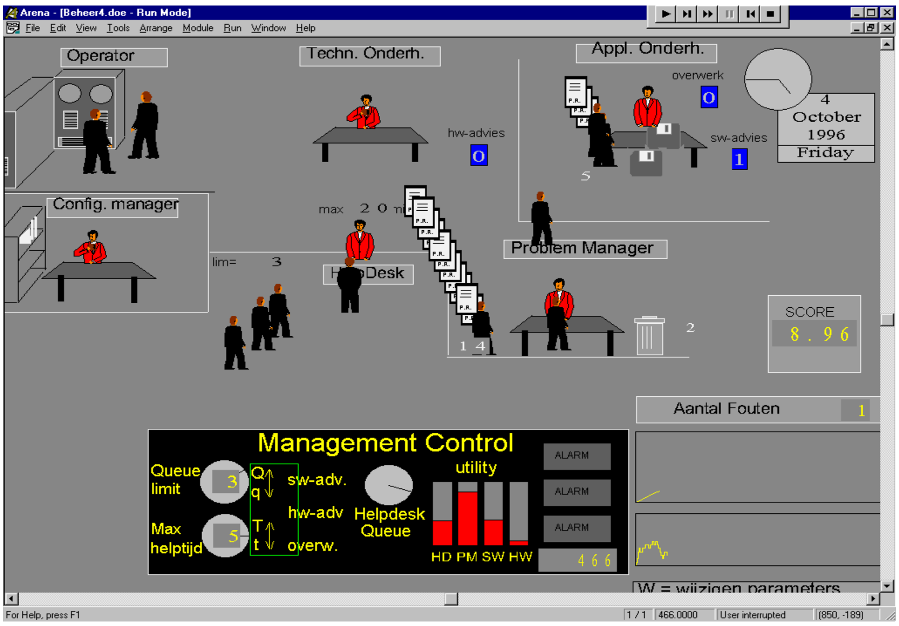

Figure 1.1: The ICT Management Simulator at the Technical University Delft

The idea for this research came up during the master's thesis research of the author (Ilkov, 1996) carried out at the Department of Information Systems Management, Faculty of Information Technology and Systems of the Technical University Delft. Based on the results of the research program mentioned above, a number of issues were identified which needed to be resolved in order to successfully apply animated simulation for the modeling of ICT management processes. These issues formed the basis for this research. More information about them is provided in the remainder of this chapter.

1.3.2 Some Issues in ICT Management

In order to cope with the challenges of managing ICT, contemporary ICT managers use a number of ICT management approaches which help them to organize in a well-structured way their organizations and optimize their effectiveness and efficiency. However, there are a number of issues which need to be resolved in order to successfully implement a particular management approach in a particular organization. Three of these issues which the research the focus on are presented below.

- *a major issue* in the field of ICT management is the lack of clarity about the way in which the ICT management approaches have to be applied in practice. These approaches cannot predict in advance the organizational structure for a specific implementation, and leave many "how-to" questions unanswered (Bootsma and van Bon, 2002). This leads to a gap between the theory and practice of ICT management (de Jong, 1997). Organizational culture, limited IT budgets, legacy systems and procedures, lack of qualified people and insufficient management commitment are among the factors that contribute to this and make the application of a particular ICT management approach a unique task for each organization. A typical result of this is that projects in this field often take much more time and resources than expected, while failing to meet the initial expectations about service quality improvement and/or cost reduction (Russian Roulette, 2002).

- *another important issue* is the fact that due to the increasing size and complexity of IT organizations, many IT managers do not have enough insight into the activities which are carried out, and their interactions and interdependencies. This influences negatively their ability to take informed decisions and act in an optimal way when problems have to be resolved, unfavorable trends are identified, or changes in the organization strategy and structure are needed. Another possible implication of this may be that even if organizations have enough technical capacity to meet peek workloads resulting from one or another abnormal event in the organization, they often do not have the necessary procedures to achieve this, and thus it is unclear how or even whether service levels can be met in such a case.

- *a third significant issue* in ICT management is that there are not sufficient tools which can be used to accurately predict the result of proposed changes in the organization (Tumay, 1995; Hlupic and Robinson, 1998), and their impact on the level of the delivered services. There are a number of tools on the market designed to assist in this, but they are very often based on static approaches like flowcharting, process modeling and spreadsheets (Tumay, 1996) and fail to capture the dynamics and stochastic aspects of the business processes in an organization. As a result of this, often additional time, effort and resources have to be spent to achieve the initially planned service levels or to resolve unforeseen side effects of the implementation of a certain organizational change or new technology.

1.3.3 Methodologies and Tools and Their Limitations

In order to be able to cope with the challenges and issues in the management of ICT, contemporary ICT managers use a large number of methodologies and tools. Most of these were developed in other problem-solving contexts and have been adapted for use in the reengineering of business processes (Kettinger et al., 1997). They vary from ICT management models and frameworks to benchmarking, flowcharting, and process modeling (Kettinger et al., 1997, Harrington, 1991, Valiris and Glykas, 1999, Klein, 1994), offering different ways of viewing, structuring, assessing and changing the processes, and aiming at improving their effectiveness and efficiency. The tools used usually support one or more of these methodologies and help managers to gain insight into the ICT management processes, to get quantitative information about key performance parameters, to identify points for improvement, and to predict and evaluate the impact of proposed changes (Yu and Wright, 1997). Most of these tools use different kinds of process models, which offer a number of advantages to the people involved in the process-reengineering endeavor. Business processes are very often sufficiently complex, and therefore carefully developed models are necessary for studying their behavior in order to improve them or build new ones (Giaglis and Paul, 1996). According to Fathee (Fathee et al., 1998) these models facilitate a systematic approach to documenting and representing the static structure of the business processes, enhance the knowledge base about the causal relations between the different processes and their sub-processes, and help to identify the missing information links and rework cycles. Busby and Williams (1993) point out that process models help for identifying the structure of the structure of the current operations, provide valued information on instituting a self-adjustment mechanism for process improvement, and help process owners and managers to identify inadequate connections between activities and duplication of activities. The pioneers of business process reengineering, Hammer and Champy (1993) also recognize the value of process models by indicating that success in process reengineering can be attributed to the creation of the flow charts, spreadsheets and process models.

However, there are two major limitations inherent to most of the currently used methodologies and tools that influence their effectiveness.

The first major limitation is their static character. They do not take into account the dynamic nature of the business processes, and the randomness and variability in their internal features and environment. This tends to constrain the possibility to capture of the real behavior of the system, and to assess the influence of randomness and variability on the system's performance (Fathee et al., 1998). Profozich argues that static tools and models are incapable of dynamic analysis, and therefore may reflect an optimistic view of the system's performance (Profozich, 1998). According to Phinney (2000), static models are not able of capturing the so-called "ripple effect" that many system dependencies have on each other. Busby and Williams argue that information provided by static process models may not be novel in nature, because they provide just a snapshot of the dynamic process and are unable to predict the system's behavior (Busby, 1993). The shortcomings of static models and tools for analyzing dynamic processes can be summarized as follows (Fathee et al., 1998):

- static models are not capable of considering variability and randomness and process capability to respond to change. They do not provide sufficient information to identify detailed deficiencies in hierarchical processes and the costs involved in correcting such deficiencies.
- the effect of variability and randomness at various hierarchical levels and the collateral impact on adjacent processes cannot be determined by static models. This deters their ability to analyze complex processes, which involve several departments and interact with other processes in the organization.
- static models lack the capability to assess the impact of process change prior to implementation. This prevents managers from developing a realistic expectation of the possible result of a proposed change, thus diminishing its credibility and the commitment of both senior management and the people involved in the process.

The second major limitation of most of the existing tools and methodologies is their inability to provide sufficion vision and insight in the modeled processes to the people taking part in the process reorganizations. Every process-reengineering project should have a clear vision, which should be implemented successfully to realize the benefits (Barrett, 1994, Crosslin, 1995). Such a vision is very important in order to gain in-depth understanding of the reengineered processes, which is crucial to the success of the reengineering endeavor. Van Ackere, Larsen en Morecroft (1993) point out that simple process maps do not typically provide sufficient understanding of the process to know what to change. Yu and Wright (1997) point out that tools are required that capture the vision and insight of non-experts towards the process-reengineering exercise. As mentioned above, most of the used methodologies were adapted from other problem-solving contexts, and they exploit graphical formalisms which cannot adequately model the people, involved in the processes on the one hand (Cho et al., 1998, Curtis et al., 1992), nor the physical system elements, such as the facility or office layout and the movement of entities throughout the facility on the other hand (Tumay and Gladwin, 1994). Curtis (1992) stresses that flexibility in representing manual tasks performed by humans is a fundamental requirement. De Vreede and Verbraeck (1996) point out that even when modeling dynamic aspects of business processes with dedicated techniques, the resulting diagrams are static, which makes it hard to thoroughly understand and analyze the dynamic characteristics of the modeled processes. Understanding these diagrams can also be a hurdle, since they use graphical formalisms which in many cases are known only to a limited group in the organization. Kettinger (1997) states that, given the high participation of non-technical personnel on BPR teams, there is a need for process capture and simulation packages that are more user-friendly and "media-rich" and allow team members easy visualize and participate in the modeling of the process. He adds that multimedia-based tools can be particularly beneficial in prototyping, as these accelerate process conceptualization, and avoid time-consuming trial and error. Giaglis (1999) also stresses the importance of graphical animation and interaction capabilities for understanding a system's behavior and the impact of proposed changes.

These limitations led us to formulate a number of points for improvement, which are presented in the next section.

1.3.4 Points for Improvement

From the presentation in the previous paragraph it has become clear that although there is a large number of methodologies and tools which can assist ICT managers in the engineering, management and reengineering of ICT management processes, there are some important limitations which impair their capabilities for process modeling, analysis and optimization. Therefore, there is a clear need for creating tools which take into account and offer adequate support for the following points for improvement:

- dynamic process modeling, i.e., the ability to model the evolution of a process over time;
- the ability to model complex processes spanning different parts of the organization, and their relationships;
- the ability to model variability and uncertainty in process behavior on every level in the process;
- the ability to experiment with the different parts of the process, as well as to assess the alternative process scenarios;
- the ability to model the people involved in the processes, as well as physical elements of the processes, such as facilities or office layout;
- the ability to visualize the execution of the processes, the work of the people and equipment involved, and the flow of entities within a process and among different processes.

The resolution of these points for improvement would result in significant benefits for ICT managers trying to (re)engineer and optimize their processes. The use of animated simulation as a way to achieve this is discussed in the next sections.

1.4 Animated Simulation of ICT Management Processes

The following sections provide information about animated simulation and the way it can contribute to resolve the points for improvement identified in the previous section. In section 1.4.1 some background information about the principles of animated simulation and its use is provided. Section 1.4.2 describes the benefits of using animated simulation for the modeling of ICT management processes. In section 1.4.3 some issues in the simulation of ICT management processes are identified, which are in the focus of the present research and its objectives.

1.4.1 What is Simulation?

Simulation is a widely used approach for studying complex systems in order to gain insight into their structure, operation and characteristics for the purpose of reaching an informed decision with regard to certain aspects of their behavior. It involves developing a model of a real system in such a way that the model mimics the response of the actual system to events that take place over time (Schriber, 1987), and conducting experiments with this model in order to understand the behavior of the system and/or to evaluate various strategies for its operation (Shannon, 1975; Pegden et al., 1995). Simulation is especially useful when it is hard to study the system under investigation directly (Doran and Gilbert, 1994; Giaglis et al., 1999) and/or for which no analytical methods are available (Arsham, 1997).

According to the used approach and physical means to build the model and carry out the experiments, we can distinguish several different types of simulation. However, for the purpose of modeling ICT management processes we are particularly interested in the *discrete-event computer simulation*. In this type of simulation the model is a computer program running on a digital computer (Fishwick, 1995) and the simulated systems are modeled as discrete-event systems, i.e., systems whose state changes occur at discrete points in time and are driven by inputs to the system, called discrete *events* (Pegden et al., 1995; Arsham, 1997; Nidumolu, 1998).

The basic idea behind using simulation for modeling ICT management processes is described in fig. 1.2. We perceive a problem in the real processes and seek a way to solve it, or we want to design new ICT management processes by using a certain ICT management approach.

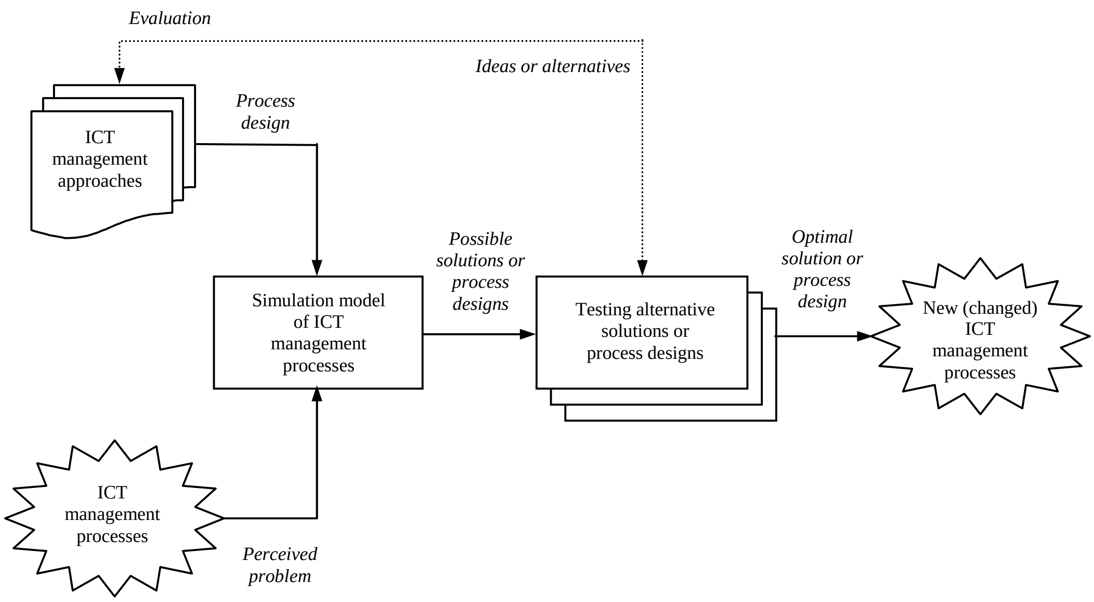

Figure 1.2: Simulation of ICT management processes

However, due to the complexity of the processes and the impossibility to carry out real-life experiments with them, it is difficult to decide whether a proposed solution really solves the problem, and which among several possible solutions is the optimal one and should be implemented in practice. In case we want to design new processes, it is often difficult to decide what the optimal process structure is given the situation at hand, and to oversee and define the complex interrelationships of the different (parts of the) processes. Therefore, we proceed by building a simulation model of the processes, which incorporates the process characteristics of interest to us, and is accurate enough to ensure a certain degree of confidence in the validity of the obtained results. Subsequently, we carry out experiments with the simulation model in order to obtain information about and to evaluate the alternative process solutions or designs. The ICT management approaches can be used in this phase to generate ideas about possible alternatives, or evaluate these alternatives against the generally adopted process structures and standards. Finally, we choose an optimum solution or process design, and implement it in practice.

A cardinal requirement for every model, and for every simulation model in particular, is that it resembles the mental model of the person it is communicated to (Chekland , 1981, Anton et al., 1993, Wierda, 1991, de Vreede, 1995). Animation enables the visualization of entities moving in the model and competing for model resources, the work and state of the model resources, as well as the state of the model by interactively displaying the values of model variables. Animated models have the potential to resemble closely the mental models of both problem owners and problem solvers (de Vreede, 1995), and provide valuable insights into model behaviour, which are not easily obtained by examining the statistical outputs (Pegden et al., 1995), and allows for better communication of results (Giaglis et al., 1999). The use of animation in simulation modeling is increasing and almost all new simulation tools and packages offer facilities for animating the simulation models (Hlupic, 1999, Mackulak and Savory, 1994).

1.4.2 Why Simulate ICT Management Processes?

The strategic role which ICT nowadays plays in an increasing number of organizations, as well as the rapid changes in the field, increase the complexity of the challenges facing contemporary ICT managers (Benamati and Lederer, 2001). As pointed out in section 1.2.2, there are a number of tools which are being used at present to facilitate ICT management and the improvement of its effectiveness and efficiency. However, these tools have some essential limitations as discussed in section 1.2.2, which restrict their practical applicability and effectiveness.

Animated simulation offers a number of advantages which help to overcome these limitations. It can be used to model the variability and the randomness of business processes, as well as the (often complex) relationships which exist among the different parts of a process. In contrast to other modeling tools, simulation is well suited to handle the stochastic and time-varying nature of business processes, as well as the non-linear interactions between process elements (Bhaskar et al., 1994). According to Tumay and Gladwin (1994) simulation tools provide ways to model entity flow including parallel flows, and the dynamic behaviour of a business process, as well as realities like randomness, uncertainty and interdependencies. It allows for the evaluation of alternative process designs and the selection of the most promising ones for implementation (Bhaskar et al., 1994). The application of simulation enhances an organization’s capabilities to achieve an in-depth understanding of internal process performance and correct allocation of resources (Fathee et al., 1998). According to Swain (1993), the ease of model building and cost economies in computing make simulation the tool of choice for modeling complex systems before proceeding to optimization.

Animated simulation is also an excellent tool to improve the understanding of ICT management processes, to give insight into the possible consequences of a proposed change in the way they are organized and to help recognizing the benefits of this change (Choi and Chan, 1994). Arend (1993) points out the value of simulation for building consensus and generating new ideas within a reengineering team. The process visualization capabilities of animated simulation facilitate to a great extent the validation of simulation results and their communication to the involved parties.

The advantages of using animated simulation for modeling ICT management processes can be summarized as follows:

– capable of capturing the dynamic nature of ICT management processes and their evolution over time;

– capable of capturing the variability and stochastic character of ICT management processes;

– enables the modeling of complex process relationships and interdependencies;

– enables the visualization of the processes under investigation.

These advantages can facilitate tackling problems like (Hlupic and Robinson, 1998) the inability to accurately predict the outcome of a change, the difficulty in capturing existing processes in a structured way, the inability to recognize the dynamic nature of the processes, or shortage of creativity in process redesign. They can contribute to a better understanding of existing ICT management processes, to identifying process bottlenecks and inefficiencies, to generating ideas for process improvement, and to testing and evaluating process change alternatives. These advantages make animated simulation a powerful tool for improving the effectiveness and efficiency of ICT management.

1.4.3 Issues in Simulating ICT Management Processes

Although, as discussed in the previous section, there are a number of advantages to using animated simulation for the modeling of ICT management processes, there are also a number of issues which need to be addressed in order to streamline the process of model development and increase its effectiveness, to reduce model development time, and to improve the reliability, reusability and validity of the developed models. Four of these issues are addressed in the present research and are described in the following paragraphs. The first three of these stem from the more general area of business process simulation, while the fourth one applies specifically to the area of ICT management simulation. The issues are defined as follows:

- *diversity in concepts and approaches* – the use of simulation as a tool for business process modeling is a relatively recent development, and although the interest in it is rapidly increasing, there is still a lack of generally adopted concepts and approaches in this area. The ones that are used are to a great extent arbitrary, and vary per project/case. This has led to difficulties in comparing results from different cases and makes it hard to benefit from the knowledge accumulated in this field. It also impedes the imposing of a well-defined structure on the simulation endeavor at the onset of the work.

- *low reusability of modeling constructs* – this is a direct consequence of the previous issue. Due to the arbitrary approaches used in each different case, the used simulation constructs are very diverse although the simulated objects and their characteristics are similar. As a result of this simulation modelers each time have to start building a simulation model from scratch, instead of using already developed and well-tested constructs, which would reduce model development time and improve model reliability, maintainability and validity.

- *poor structuring of the modeling process* – as mentioned above, the approaches used in different simulation endeavors are in most cases arbitrary. Although a number of simulation approaches have been developed, they have a more general character and fail to capture the specific aspects of simulating a specific type of processes. Therefore, a consistent approach to simulating ICT management processes is needed that takes into account the specific aspects of these processes and allows for a well-structured model development.

- *little experience with the development and use of simulation models of ICT management processes* – although it is clear that animated simulation offers a number of advantages compared with the traditional process analysis and modeling tools, and has been successfully used in a number of process redesign endeavors, little is known about the specific benefits and capabilities which simulation offers for the modeling of ICT management processes. Compared to the traditional organizational processes, ICT management processes are relatively new, and are characterized by a very rapid (sometimes even chaotic) expansion, critical dependency on the implemented technology, high demands with regard to the knowledge of the people involved in the processes, and high exposure to the newest technological developments. This makes ICT management processes very dynamic and technology-oriented and imposes additional requirements on the use of simulation for modeling such processes. Very few cases of ICT management processes simulation are reported in the scientific literature, and this restricts the awareness of ICT managers and process (re)designers and prevents them from using the advantages it offers.

1.5 Research Objectives and Research Questions

Based on the issues in ICT management described in section 1.3.1, and the limitations of the existing methodologies and tools and the identified points for improvement, the research objectives for the research project were defined and the main research question was formulated. These are presented in the next sections. The discussion begins with a demarcation of the research discussed in section 1.5.1. The objectives of the research are then defined in section 1.5.2. The main research question and its sub-questions are formulated in section 1.5.3.

1.5.1 Demarcation of the Research

The focus of this research is on simulating the processes carried out in ICT management. Therefore, the objects of research in this project are the organizational structures, tasks and procedures used in these processes, as well as the people involved in the processes, the information they exchange and the equipment they use. These objects and their characteristics were the basic building blocks used to build simulation models of ICT management processes.

The research focused on processes on the operational level of ICT Management (for a detailed discussion on the different levels, at which ICT management processes are carried out, see Looijen, 1998). For these processes the process steps, as well as the input and output of these steps are relatively well defined and formalized. This makes it easier to achieve a formal representation of the processes and capture them in a simulation model. Processes at the tactical and strategic level which incorporate large ill-structured steps with (in many cases) arbitrary form and content were left out of consideration.

1.5.2 Objectives of the Research

Based on the points for improvement presented in section 1.2.3 and the issues in using animated simulation for the modeling of ICT Management processes, and taking into account the demarcation of the research presented in the previous section, the objectives of the research were formulated. These objectives can be defined as follows:

- Provide a conceptual basis for building simulation models of ICT management, which will allow for capturing the following aspects:
  - Generic structural elements of ICT Management processes;
  - Communication and coordination mechanisms used in ICT Management.
- Create facilities for building simulation models of ICT management processes, such as:
  - Simulation constructs for modeling generic structural elements of ICT management processes;
  - A library of object classes for simulating ICT management processes.
- Develop an approach for the simulation of ICT processes with the following characteristics:
  - Define a well-structured sequence of steps that need to be taken in order to develop a simulation model of ICT management;
  - Describe the aspects of ICT management processes that have to be incorporated in a simulation model.
- Investigate the possibilities of animated simulation for supporting the application of ICT management approaches and for improving the effectiveness and efficiency of ICT management, by exploring the following aspects:
  - Benefits of using animated simulation to resolve issues related to implementing ICT management approaches in practical situations;
  - Possibilities of animated simulation for gaining insight into and for optimizing existing ICT management processes.

The attainment of these objectives will ‘pave the way’ for building simulation models of ICT management, and for using them to improve the quality and efficiency of the ICT services production. The objectives provide the basis for the formulation of the research questions of the research project. These questions are presented in the next section.

1.5.3 Research Question

The research questions for the present research project were formulated considering the problem area, the objects of research, and the research objectives. They include one main research question and four research sub-questions.

The main research question of the research project was defined as follows:

Main Research Question:

What theoretical developments and practical facilities are necessary for applying animated simulation for the modeling of ICT Management processes?

Before resolving the main research question, four sub-questions have to be answered. Each of them deals with a different aspect of the research. These sub-questions are presented below.

1st Research Sub-Question:

Which aspects of the daily ICT management practice are relevant to the building of simulation models of ICT management processes and how they can be used for defining a conceptual basis for developing such models?

This sub-question deals with the need to develop a conceptual framework for building simulation models of ICT Management processes. The framework has to consist of concepts which reflect aspects of the daily ICT Management practice relevant to building such models.

2nd Research Sub-Question:

What kinds of facilities are necessary for building animated simulation models of ICT management processes, and how can they be developed?

This sub-question deals with the facilities necessary for building of animated simulation models of ICT management processes. It is very important to specify the kind of facilities that have to be developed, and to investigate the feasible ways for their development.

3rd Research Sub-Question:

What approach can be used in order to build an ICT Management processes simulation model in an effective and efficient way, and what are the steps that have to be followed?

This sub-question reflects the need to define a well-structured approach consisting of a sequence of steps that have to be taken in order to build an ICT management simulation model in an effective and efficient way. This will allow for imposing a structure on the simulation endeavor at the onset of the work, reduce model development time, and ensure that all relevant aspects and characteristics of the modeled processes are taken into account, thus improving the quality and validity of the obtained results.

4th Research Sub-Question:

How can the conceptual basis, approach and facilities for simulating ICT Management processes be applied in practice for modeling such processes?

The fourth sub-question focuses on the application of the elements dealt with in the previous three sub-questions in order to validate the ideas and facilities presented as part of them. It also deals with the way in which simulation can help for analyzing and modeling of ICT management processes, the functionality a simulation model should have, and the benefits and problems related to its use.

To find the answers to these questions one needs a suitable research methodology. This methodology needs to encompass both the theoretical and practical aspects of the research. It also has to match the specific requirements of the present project. These issues are discussed in the following section.

1.6 Research Methodology and Research Approach

This section describes the adopted research methodology for the present research project and the research approach in which this methodology is used for answering the research questions. The section is divided into three parts. The first part (1.6.1) describes the characteristics of the research methods included in the methodology. The second part (1.6.2) presents the justification of the research methodology by examining the characteristics of the research project versus the characteristics of the research approaches. The third part (1.6.3) presents the steps of the research approach.

1.6.1 Research Methodology

The research methodology for the present project was devised based on the object of research, and investigating the taxonomies of scientific research approaches developed by Galliers in (Galliers, 1992), and Yin in (Yin, 1989). For the purposes of this research and in line with the definition provided by Checkland (1981) we define *research methodology* as *a compilation of research methods, which complement each other, and are governed by a set of principles and a common philosophy for solving targeted problems*. The research methods of which the used methodology consists are a *literature study* of the available publications in the scientific literature on animated simulation, business process reengineering and ICT Management, the *case study research* method, and the *actions research* method. A short description of these methods follows.

- *The literature study* is an important part of every research project. It is necessary for an investigation of the concepts and theories developed in the specific scientific field, as well as for exploring the findings of other researchers and reviewing the employed research methods and achieved results. As Miles (1979) explains, the literature study is essential for defining a conceptual framework at the outset of the research, and for refining this framework in the course of the work. It also helps to gain new insights into the problems under investigation, and to ensure that the present research is not just a replication of a past research project.
- *The case study research* was used extensively throughout the present research project. According to Benbasat (1987), '*a case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or*

a few entities, the boundaries of the phenomenon are not clearly evident at the outset of the research, and no experimental control or manipulation is used'. Yin (1989) describes the typical characteristics of situations where the case study approach is feasible as follows:

– There is a need to study the phenomenon of interest in its natural setting. Study of practice-based problems where the experience of actors is important and the context of action is crucial.

– The problems reside within a rapidly changing environment, or one where a steady state is not maintained long enough to permit proper research of the phenomenon under investigation.

– There is an emphasis on the 'why' and 'how' questions, i.e. understanding the nature and complexity of the process taking place.

– There is a lack of previous studies and elaborated theoretical understanding (i.e. testable hypotheses) with regard to the phenomenon of interest.

The case study research approach allows for capturing the relationships that exist in a particular situation. According to Galliers (1994) this happens usually within a single organization or organizational grouping. The case study enables the capture of reality in great detail, and the analysis of a relatively large number of variables (in comparison, for example, with laboratory or field experiments). Hamilton and Eves (1994) point out that case studies are among the most employed research strategies in the field of Information Systems. As Lawler asserts (Lawler et al., 1985) *'the case study approach is helpful in developing and refining generalizable concepts'*. In case of multiple case studies it is possible to relate variability in context to constants in processes and outcomes. Yin (1994) distinguishes three types of case studies: *descriptive, exploratory and explanatory*. For the purposes of this project the last two types of case study were used.

- *The actions research* is an applied research method, which aims at obtaining results of practical value to groups with which the researcher is allied, while at the same time adding to theoretical knowledge (Galliers, 1994). Very often it is used as complementary to the case study research approach. The role of the researcher performing actions research is to associate himself with the practical outcome of the research in addition to seeking to identify theoretical outcomes (Foster, 1972). Argyris (1989) defines actions research as *'a research in which scientists engage with participants in a collaborative process of critical inquiry into problems of social practice in a learning context'*. The strengths of this form of research include the very practical benefits that are likely to accrue to the client organization as a result, and the fact that the researcher's biases are known at the beginning of the research (White, 1985). The close relation with the subjects of research allows for applying a theory and evaluating it at the same time (Clark, 1972; Galliers, 1991). A number of researchers have successfully used action research in the field of information systems (see for example De Wijs, 1995, Van Meel, 1994, Dur, 1992). According to de Wijs (1995), the key characteristics of the action research are:

  – The researcher attempts to arrive at improved theories, while at the same time participating in the implementation of interventions;

  – Interventions are specified partly by the researcher, who participates intensively with his/her research environment to obtain continuous feedback

> As Galliers (1994) asserts, both the case study research approach and the actions research approach can be used to build, test and extend theories, and they are both applicable to organizations. The main benefit of using the action research approach in the present research project is the fact that it comprises the direct involvement of the researcher in the processes under investigation. This enables him to gather very detailed information about these processes, which is crucial to the successful development and use of a simulation model.

The described research methodology was implemented in the research approach, developed for the present project. The relation between the research methods constituting the methodology and the phases of the project fulfillment is explained in section 1.6.3.

1.6.2 Justification of the Research Methodology

When the research methodology was devised, the characteristics of the present research project were taken into account and the relevance of the chosen research approaches with regard to these characteristics was considered. These characteristics can be described as follows:

- *Scarcity of established generic models and theories* – as mentioned above, the simulation of organizational processes in general, and ICT management processes in particular, is a relatively recent development and there are few generally accepted models and theories reported in the scientific literature. Therefore there are no well-established scientific methodologies and approaches which a researcher can use.
- *Necessity to examine the phenomenon in its natural setting* – the only way to study ICT management processes is in their natural setting, i.e., the place where they are carried out. These processes cannot be reproduced in a laboratory environment, neither can they be studied using field experiments.
- *Problems reside within a rapidly changing environment* – the ever-increasing speed of developments in the area of ICT make the ICT management organization one of the most rapidly changing organizational environments. Pressures from competition and the scarcity of qualified personnel are other well-known factors which contribute to the agility and volatility in the field.
- *Necessity for an in-depth and first-hand understanding* – detailed knowledge and understanding of ICT management processes and their characteristics is essential to the successful development of a simulation model of these processes. Due to a number of factors, among which poor documentation, considerable workloads and process complexity, in many cases this knowledge can only be obtained first hand, by means direct observation and/or involvement of the researcher in the processes.
- *Necessity for generalization of the research results* – in order to validate the obtained research results and to improve their reusability, they have to be placed in the context of a larger body of knowledge and generalized so they can be applied to other cases and/or contexts. This is even more so for the area of ICT management processes simulation, where generally established models, theories and approaches are scarce.

The correspondence between the research project characteristics and the relevant research approaches is given in table 1.1.

Research Project Characteristics	Relevant Research Approaches
Scarcity of established generic models and theories	Case study, literature study
Necessity to examine the phenomenon in its natural setting	Case study, actions research
Problems reside within a rapidly changing environment	Case study
Necessity for an in-depth and first-hand understanding	Action research
Necessity for generalization of the research results	Case study, action research, literature study

Table 1.1: The correspondence between the project characteristics and the research approaches

1.6.3 Research Approach

With the research objectives and the research question in mind, a research approach for the project was developed. This approach describes the steps that were taken in order to achieve the goals of the research and incorporates the methods of the adopted research methodology, described in section 1.5.1. The research approach consists of 6 phases, depicted in fig. 1.3, which reflect the logical sequence of steps that were taken in order to carry out the research. The results of these phases are reported in the remaining chapters of this book. The phases are described as follows:

- *Phase 1:* This phase comprises the activities that were carried out in order to define the problem domain of the research project, to formulate the goals of the project, to identify the steps that needed to be taken in order to achieve these goals, and to define the sequence in which these steps had to be carried out, as well as their interdependencies. The phase involved the identification and formulation of the problems to be addressed by the research project, the formulation of the main research question of the project and its sub-questions, as well as the development of a suitable research methodology and an initial research approach implementing this methodology. The result of the phase served as a blueprint for the further work on the project. They are described in chapter 1 of this thesis.
- *Phase 2:* In this phase the theoretical background for the research was developed based on literature study and an explorative case was carried out in order to identify characteristics of ICT management processes relevant to the building of simulation models. Case study and action research techniques were employed during the explorative case in order to gather the necessary information. This resulted in the formulation of a set of generic structural elements of ICT management processes and the definition of their characteristics and relationships. The results of this phase are described in chapters 2 and 3 of this thesis.
- *Phase 3:* Based on the set of generic structural elements formulated in the previous phase, in this phase a conceptual framework for simulating ICT management processes was

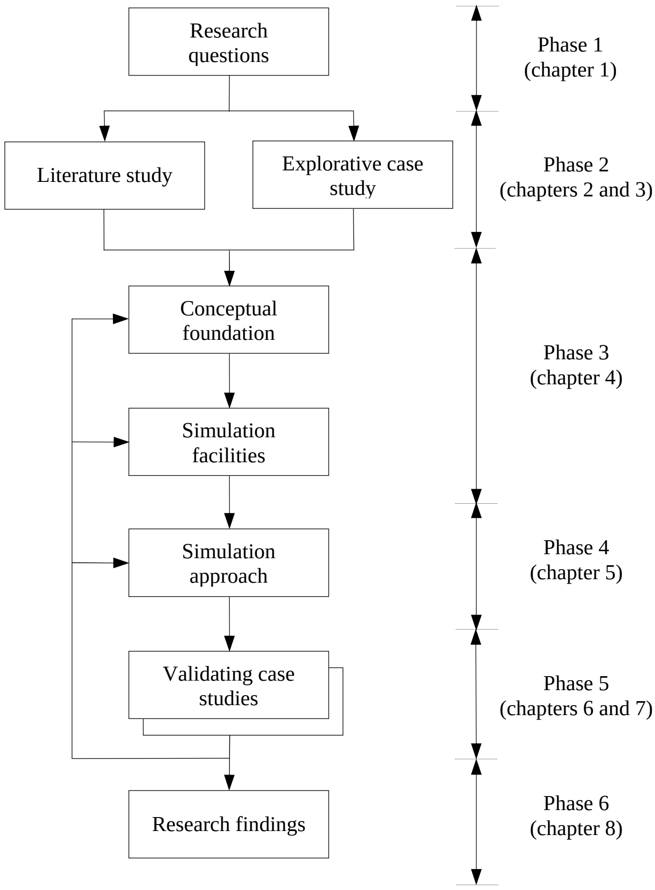

Figure 1.3: The Phases of the Research Approach

defined. Based on the conceptual framework, object-oriented techniques were used to develop a library of object classes for simulating ICT management processes. This library was implemented in the ARENA® simulation environment as a dedicated set of modeling constructs (simulation template). The results of this phase are described in chapter 4 of this thesis.

- *Phase 4*: In this phase a structured approach for the simulation of ICT management processes was developed that describes the steps that have to be taken in order to build an ICT management simnulation model. The approach reflected the developments in the area reported in the literature, as well as the personal experience and ideas of the author. The steps of the approach were used and refined during the test cases carried out during the next phase of the project. The results of this phase are described in chapter 5 of this thesis.

- *Phase 5*: In this phase the developed facilities and approach for the simulation of ICT management processes were applied in two test cases based on practical situations in order to test and improve their structure and applicability, and to get an indication of the possibilities and benefits they offer to the model developer. The test cases were carried out in two large organizations in The Netherlands. The cases and their results are described in chapters 6 and 7 of this book.

- *Phase 6*: In this phase the results of the test cases were used to draw conclusions about the applicability and validity of the proposed conceptual framework, facilities and approach for the simulation of ICT management processes. The research findings of the project were assessed against the main research question and its sub-questions defined in phase 1, and directions for future research on the topic were proposed. The results of the phase are described in chapter 8 of this book.

1.7 Summary and Organization of the Dissertation

In this chapter the foundations for the present research project were presented. The challenges of effective and efficient ICT management in contemporary organizations were discussed. The existing approaches and tools used to cope with these challenges were described. A number of limitations of these approaches and tools were identified, and the need for additional research in order to overcome them was explained. Based on a concise review of theoretical developments reported in the literature, the expected advantages of animated simulation for coping with these limitations were presented, and a number of issues in the simulation of ICT management processes were discussed. On the basis of these issues, the problem area, research objectives and the main research question and its sub-questions for the present research project were defined. The research methodology for the research project and its justification were presented. Finally, the research approach implementing this methodology, and its phases were discussed.

The rest of this book is organized as follows. In chapter 2 the theoretical foundations of the project are presented. In chapter 3 an exploratory case study is described, which was used for defining the conceptual framework of the research. This framework is presented in chapter 4, together with a library of object classes for simulating ICT management processes, which was developed on the basis of the framework. In chapter 5 an approach for the modeling and simulation of ICT management processes is presented. In chapters 6 and 7 the application of the object class library and the simulation approach in two test cases carried out in large organizations in the Netherlands is described. Finally, in chapter 8 a summary of the research findings is provided and directions for future research are proposed.

Chapter 2

The Research Framework: Theories on ICT Management, Business Process Reengineering and Animated Simulation

2.1. Introduction

As indicated in the previous chapter, the current research on ICT management processes simulation is based on three main scientific fields: ICT management, Business Process Reengineering and Discrete-Event Simulation. The theoretical and practical developments in these fields underpin the motivation of the research and the definition of its goals, and provide the criteria and frame of reference for assessing the research findings. In this way, these fields form the theoretical framework of the research. This is depicted on fig. 2.1.

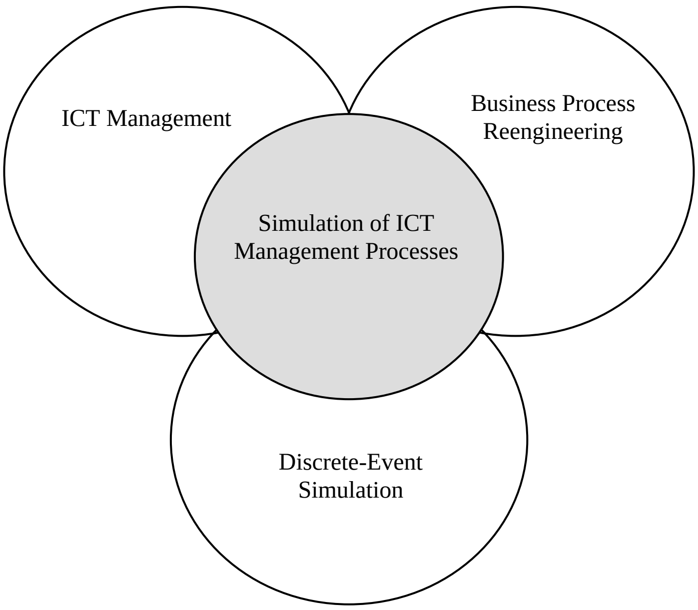

Figure 2.1: The theoretical framework of the research

The field of ICT management and the models and approaches used in it provide the information about the processes on which the research is focused, the driving forces behind them, their goals, contents, interrelationships and the environment in which they operate. It also provides a framework, which can be used to assess the performance of these processes, identify opportunities for increasing their effectiveness and efficiency, and define the changes to the existing ICT management processes necessary for realizing these opportunities. Business process reengineering provides the methodologies and techniques for implementing these changes in practice. It describes the necessary steps and highlights the issues that have to be taken into account when carrying out the changes. Discrete-event simulation is a powerful tool for modeling and visualizing the work of stochastic discrete-event systems. It can be used to model ICT management processes in order to gain insight into the way they operate, identify bottlenecks and problems and test different scenarios to overcome them, and predict the impact of changes to the processes.

This chapter provides more detailed information about these three fields. The goal of the chapter is to discuss the state-of-the-art in the fields, and identify omissions in theory, which are addressed in the present research. For each field an overview of the background and the basic principles is provided, followed by a discussion of the main theoretical and practical developments. Finally, the possibilities and advantages of these developments are discussed, possible points for improvement are identified and the issues, which are in the focus of this research are presented.

The chapter is structured as follows. In section 2.2 information about ICT management and some widely accepted theories and approaches in this field are provided. Section 2.3 focuses on the principles and main developments in the field of business process reengineering. Section 2.4 provides information about discrete-event simulation and its application for the modeling of business processes. Finally, in section 2.5 conclusions are made about the developments in these fields, omissions in theory which need to be addressed are indicated, and the issues on which the research focuses are discussed.

2.2. ICT Management Approaches

The ever-increasing complexity and use of ICT and the growing dependency of organizations on high-quality ICT services makes the effective and efficient ICT management an increasingly difficult and challenging task. In order to assist ICT managers with this task, a number of ICT management approaches have been developed. The main goal of these approaches is to describe the tasks and processes that have to be carried out in ICT management, describe their interrelationships and the way in which they have to be coordinated, and provide a framework for the management of an ICT organization. In the following sections, two prominent approaches to ICT management are discussed – MCM of Information Systems and ITIL. Several other important approaches are also covered.

2.2.1. Management, Control and Maintenance of Information Systems

A widely-known approach to the management of ICT is the so-called *Management, Control and Maintenance of Information Systems (MCM)* developed by Looijen (1998). This approach covers a broad range of ICT management topics and provides a coherent framework for the planning, implementation and operation of ICT management in an organization. The main elements of the approach are the *MCM Paradigm*, the *MCM Tasks Frame of Reference*, the *(Extended) State Model* and the so-called *Triple Model of MCM*. These elements are described in the following paragraphs.

The MCM Paradigm

In order to position the MCM of Information systems, the MCM paradigm is introduced. In this paradigm, organizations are viewed as dynamic systems. According to Brussaard (1980) any such system can be modeled in terms of a real system (RS) and an information system (IS), which controls and determines the behavior of the real system. If we apply the same principle to the IS, we can make a distinction between the "technical" part of the IS and its management, control and maintenance (fig. 2.2). In this way, MCM consists of continuous control tasks, which ensure that the information system operates according to the preconditions and requirements imposed on the utilization and the technical characteristics of the system components (Looijen, 1998). The combination RS-IS-MCM exists in an environment, which exercises different kinds of influences on them. Examples of such influences are new technological developments (technical), government regulations with regards to information and privacy (informational), economic situation at national/international level (economic) and organizational changes resulting from mergers, acquisitions or disposal of certain business units (managerial) (Looijen, 1999). The relationship among RS, IS, MCM and the environmental influences are captured in the MCM paradigm, which is depicted on fig. 2.2.

The MCM Tasks Frame of Reference

In order to ensure that the IS functions according to the predefined requirements and within the imposed constraints, an exhaustive list of tasks, which have to be carried out in the daily practice of ICT management has been defined (Delen and Looijen, 1992, Looijen, 1998).

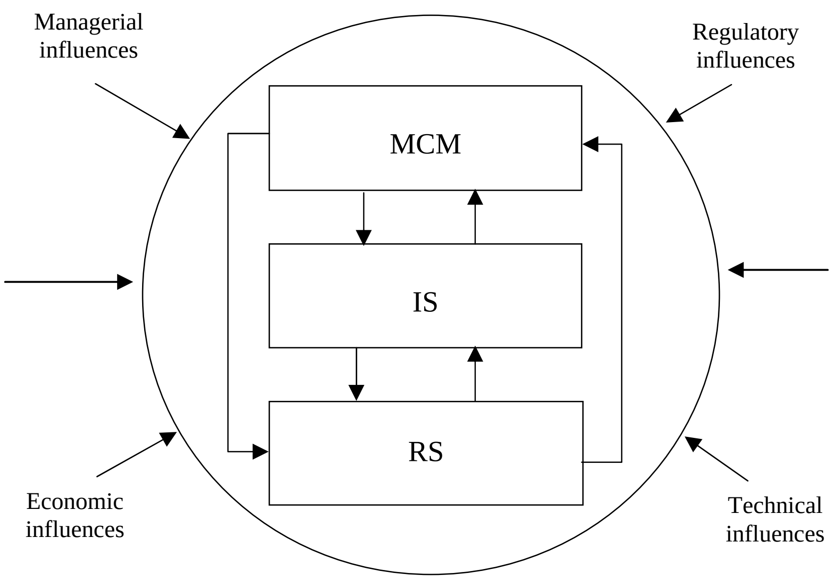

Figure 2.2: The MCM Paradigm

These tasks cover a wide range of topics in ICT management, varying from the formulation of the ICT strategy of the organization, to the tactical and operational implementation of this strategy, to the management of software applications, technical infrastructure, personnel and ICT budgets. In MCM these tasks are structured and organized to form a frame of reference, which defines the contents of the most important aspects of ICT management and their interrelationships. On the basis of their nature and coherence related tasks are combined into clusters called task fields, and related task fields are combined into task areas. The task areas covered by MCM are management (M), personnel management (PM), technical support (TSu), general business support (GBS), operational control (OC), maintenance technical infrastructure and operational support (MTI-OS), technical services (TSe), utilization management (UM), functional maintenance (FM) and application maintenance (AM). In this way a comprehensive frame of reference is formed which reflects the contents and function of the tasks and their various interrelationships. Guidelines are also provided with regards to the way in which tasks from different task areas and/or task fields can be related to one another and combined into processes which (possibly) span different parts of the organization and aim at achieving a certain goal in the ICT management practice. A more detailed discussion of the tasks, task fields and task areas of MCM can be found in (Looijen, 1998).

The State Model

The state model (SM) describes the different stages of the development, utilization and management of an information system. The SM takes a nonlinear approach to the life cycle of an IS and overcomes essential limitations of the linear “waterfall” approaches developed earlier. These limitations are related mainly to the fact that when an information system is developed and taken into production, it undergoes different kinds of changes, some of which require that a number of (or all) preceding stages take place again, and this leads to parallels between the various stages, which cannot be modeled by the waterfall approach. Furthermore, the SM is based on the assumption that MCM is present in all stages of the life cycle of an information system, rather than being the last stage. In order to capture these aspects the SM distinguishes a number of states in the life cycle of an information system and defines the task areas and task fields relevant to each state.

According to the state model, the life cycle of an IS begins with the state *information policy and planning* (IPP) in which the information policies and plans of the organization are developed and the characteristics of the needed information system are defined. The next state is *development* (D), which entails the design and construction of the information system. The state *acceptance and implementation* (AI) follows, in which the information system is assessed and is either accepted and implemented in the organization, or goes back to the previous state for further development. The following three states take place in parallel and are related to the operational use of the IS. In the state *utilization* (U) the functionality of the IS is used. The state *exploitation* (E) is related to keeping the IS operational and functioning according to the predefined requirements and constraints. In the state *maintenance* (M) the IS or parts of it are being changed as a result of planned maintenance or modifications initiated from the states E and U. These states and their relationships are depicted on fig. 2.3.

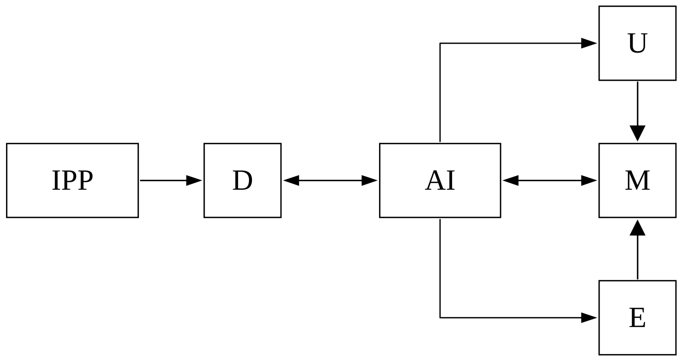

Figure 2.3: The state model

In order to capture the development and evolution of the IS over time, the *extended state model* (ESM) is introduced on the basis of the state model. This model takes into account the different kinds of changes and modifications that can be made to the information system after it has been put into use, and the impact they can have on the states utilization and control. Two kinds of changes and modifications in the state M are defined. The first kind are those that result in little or no changes in the states U and E of the IS. The second kind consists of the ones that result in changes in at least one of the states U and E. In connection to this, two sub-states of the state M are defined – M1 (minor/no impacts) and M2 (major impact). In this way, if the information system is in states U1/E1, after M1 changes are carried out it stays in U1/E1, while M2 changes make it advance to states U2/E2. The relationships between the states and the sub-states in the ESM are depicted on fig. 2.4.

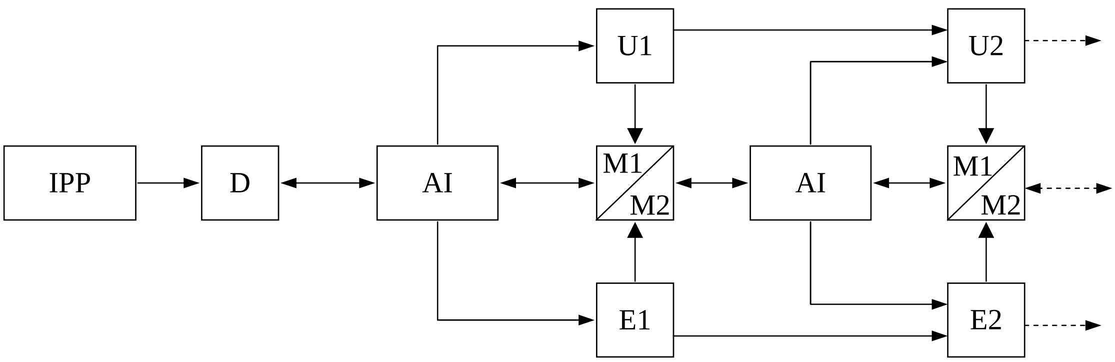

Figure 2.4: The extended state model

Triple Model of MCM

The MCM tasks frame of reference describes the management of ICT as a set of tasks grouped into task fields and task areas on the basis of their nature and coherence. A closer look at the set of tasks, however, shows that these tasks are related to three main aspects of ICT management – the management of functionality, the management of software applications and the management of technical infrastructure of the IS. Furthermore, some of them are carried out to enable and support the daily operation and use of the IS, while others are used to ensure that the middle- and long-term ICT goals of the organization are met. These relationships are not necessarily explicitly reflected in the grouping of tasks into task areas, i.e., a task area can be related to one or more of these aspects. In order to capture this, the *Triple Model of MCM* (TMM) was developed. In this model the following three forms of ICT management are defined:

- *functional management* (FM) – responsible for the maintenance and control of the functionality of the IS. FM is strongly related to the utilization of the information system and is therefore often placed on the side of the user. Includes the support and evaluation of the utilization of the IS, reacts to deficiencies in this utilization and takes care of new requirements, which can result in a modification of IS functionality.
- *application management* (AM) - responsible for the maintenance and control of the application software and databases. Includes the analysis and implementation of upgrades and modifications to the software applications and databases, as well as the development of new applications. Provides support for and resolves software-related problems. Takes care of the planning, documentation and procedures for the distribution and use of software.
- *technical management* (TM) – responsible for the maintenance and control of the technical infrastructure of the IS and the supporting system software and databases. Ensures the continuous availability of the technical infrastructure and the achievement of the agreed service levels. Includes monitoring and (proactive) infrastructure management, problem solving and disaster recovery. Evaluates and implements changes and modifications to the technical infrastructure.

Next to the three forms of ICT management, the following three levels at which MCM tasks are carried out are defined with regards to the time frame within which a task is carried out:

- *strategic level* – comprises tasks aimed at achieving the long-term ICT goals of the organization. These tasks include the formulation of the ICT strategy and its goals, the acquirement of the hardware, software and human resources needed to achieve these goals, as well as the planning of the structure and relationships of the three forms of management and their place in the organization in relation to the ICT strategy.
- *tactical level* – comprises tasks aimed at achieving the middle-term ICT goals of the organization. These tasks cover the translation of the ICT strategy of the organization into middle-term objectives, and the activities necessary for meeting these objectives. Includes the hiring and training of personnel, acquisition and deployment of basic software, the deployment of hardware and the building of technical infrastructures, as well as the planning, acquisition, deployment and administration of application software and tools.
- *operational level* – comprises tasks aimed at achieving the short-term ICT goals of the organization. The tasks at this level are related to the daily operation, utilization and maintenance of the information system. This includes the acceptance, operation and control of hardware and physical storage devices and system processes, the control of utilization and performance of application software, the resolution of hardware and software incidents and problems, the carrying out of changes to the technical infrastructure, functional system management and the management of application and business data. Tasks related to user training and support and the maintenance of manuals and procedures are also carried out here. Providing advice with regards to the operation of the information system and participation in projects are also important tasks at this level.

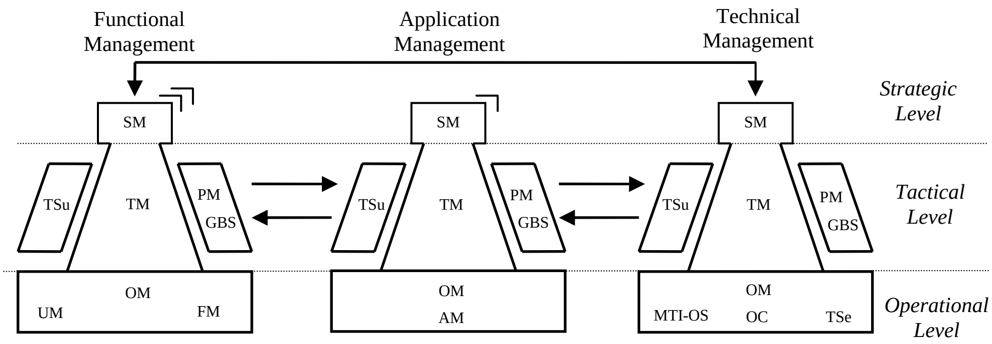

Figure 2.5: The triple model of MCM

The relationships between the three forms of management, the three levels of management and the task areas from the MCM tasks frame of reference are captured in the Triple Model of MCM depicted on fig. 2.5. In the figure the acronyms of the names of the task areas are used as defined in the paragraph about the MCM tasks frame of reference above.

2.2.2. IT Infrastructure Library

Another prominent approach to the management of ICT is the IT Infrastructure Library (ITIL). ITIL is a collection of best practices, which cover different subjects of ICT management, and provide a framework for organizing IT Service Management, which is defined as *the management of the entire ICT sector in an organization, its infrastructure and its activities, as a coherent set of interrelated processes aimed at providing business-justified services to the organization* (Hendriks and Carr, 2002).

ITIL aims at providing a *comprehensive, consistent and coherent set of best practices for IT Service Management processes, while promoting a quality approach in achieving business effectiveness and efficiency in the use of information systems* (CCTA, 2001). It was developed in the late 1980s as a set of about forty books describing IT service management processes. Ten of these books form the so-called “core guides” and cover the areas of Service Support and Service Delivery. They are complemented by over 30 other guides, which cover a wide range of ICT management issues varying from business continuity management to cabling. Guides covering similar issues are combined in nine sets. Six of them cover the delivery and support of ICT services, the management of computers, networks and software, as well as ICT services management issues. The three other sets deal with the formulation of the strategy and management of the IT environment and with the management of the workplace (office) environment.

In order to respond to changing business requirements in the area of IT service management, improve the scalability of the framework and the navigation through the different processes, ITIL has recently undergone a revision and consolidation. As a result of this the following five basic elements covered by ITIL have been defined (CCTA, 2001): the business perspective; managing applications; delivery of ICT services; support of ICT services; managing the infrastructure. Each of these elements interfaces and overlaps with each of the other four. The relationships among these elements have been likened to the pieces of a jigsaw puzzle, some of which have a precise fit, and others overlap and do not fit accurately together. The movement of one piece can affect one or more of the neighboring pieces, and their imprecision causes friction and instability. This resembles the behavior and interaction of the different ICT management processes, where no clear demarcation lines can be drawn, and many management problems are caused by their imprecise nature. The jigsaw concept for the five ITIL elements is depicted on fig. 2.6.

Each of the five elements consists of a number of processes described in the original version of ITIL, and additional new material. Two of these elements - the delivery of ICT services and the support of ICT services - cover the core processes of the ITIL framework on IT service management and are described in the *Service Delivery* (CCTA, 2001) and *Service Support* (CCTA, 2000) books respectively. The books on other three elements are expected in the near future. A concise description of each of the elements follows.

Service Delivery

As mentioned above, this is the first book of the two “core” books of the ITIL framework. It covers the processes, which are necessary for the planning and delivery of ICT services according to the requirements and within the constraints imposed by the (users) business. It is concerned with setting up service agreements and ensuring that these agreements are met. An extra emphasis is laid in the book on the way of delivering ICT services – the priority of customer satisfaction is raised from ‘nice’ to ‘essential’ (Hendriks and Carr, 2002). The processes covered by this book aim at achieving middle-term goals for the ICT management organization and can be found on the tactical level on fig. 2.5. They are as follows (CCTA, 2001):

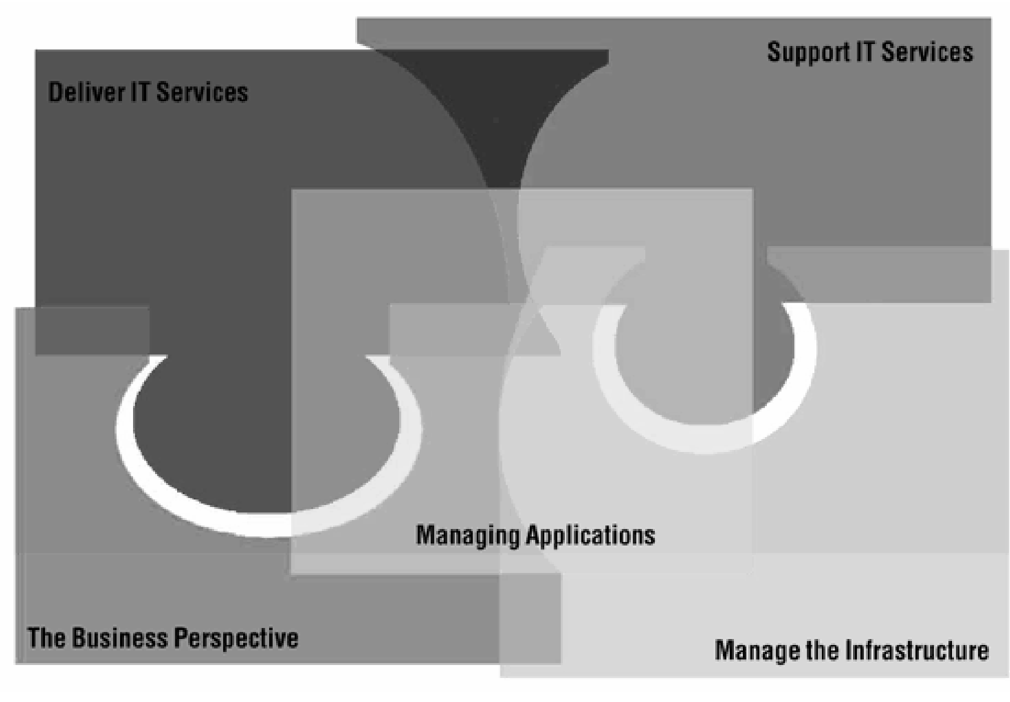

Figure 2.6: The jigsaw concept of ITIL (Source: ITIL, 2001)

- *Service Level Management* – the main goal of Service Level Management is to maintain and improve the quality of ICT services by continuously agreeing, monitoring and reporting on ICT service levels, and taking corrective actions in case of service level degradation. A key responsibility of SLM is making service level agreements (SLAs) with the users, and make sure that these agreements are met. The SLA's should cover all ICT services provided to the client. An important aspect of the work of SLM is to ensure that underpinning contracts are in place with external parties, on which the delivery of one or more services depends. Another aspect of the work of SLM is the reviewing of actual service levels, to ensure that they are maintained and gradually improved in a cost-efficient manner. Service level management provides the basis for managing the relationship between the ICT management organization and its customers.
- *Capacity Management* – the main goal of capacity management is the optimal planning and deployment of ICT resources in the organization, in order to ensure that the current and future capacity demands of the ICT organization are met in a timely and cost-effective manner. It involves monitoring of performance and throughput of ICT services and infrastructure components, carrying out tuning to improve the efficiency of resource utilization, understanding current capacity requirements and forecasting of and planning for future capacity requirements. The accurate assessment of the impact of proposed changes on the current and/or future capacity is also an important part of this process. Good capacity management enables the provider of ICT services to provide service levels as agreed in the SLA's. Capacity management is closely related to Service Level Management and to the change management, problem management and ICT service continuity management processes described below.
- *Availability Management* – the goal of the Availability Management process is to ensure that the ICT organization delivers cost-effective ICT services with a level of availability that meets the demands of the users and enables them to satisfy their business objectives. This is achieved by determining the requirements of the business, comparing them with the current capabilities of the ICT organization and the ICT infrastructure, and in case a mismatch between these two exists, providing the business with options and alternatives for overcoming this mismatch. Availability management involves the continuous measurement, assessment and reporting of the availability of the services, and requires insight into the causes for service disruption and the corresponding recovery times. Close cooperation with incident and problem management is very important for ensuring that the necessary corrective actions are taken in case of disruption of the availability level.
- *Financial Management for IT Services* – the main goal of Financial Management for IT Services is to ensure that the assets and resources necessary for the provision of ICT services are utilized by the ICT organization in a cost-effective manner. This is achieved by carrying out budgeting, accounting and charging for ICT services, and includes calculating the costs of ICT services provision, finding of revenues to cover these costs, managing the spending of these revenues, charging clients, and determining the return on ICT investments. The financial management for IT services plays a key role in the process of determining whether a change to the existing infrastructure and/or services should be implemented by helping for finding a balance between costs and expected benefits. It works in a close relationship with Service Level Management and Capacity Management, and is strongly dependent on the process of Configuration management described below.
- *IT Service Continuity Management* - the main goal of IT Service Continuity Management is to ensure that in case of a disruption of the ICT services, these can be recovered within

the time-frame agreed with the business, thus supporting the overall business continuity. This requires the planning and implementation of recovery measures and procedures for disruptions, which can vary from a failure of a single service or application, to a complete loss of the business premises. The IT Service Continuity Management focuses on the ability of the ICT organization to continue to provide a predetermined level of ICT services so that the minimum requirements of the business are met. It also aims at achieving a balance between risk reduction measures and recovery options. Effective configuration and change management are key to the successful implementation and functioning of this process.

Service Support

This is the second "core" book of the ITIL framework for ICT services management. It covers six closely related processes, which are concerned with ensuring that the users have access to the appropriate ICT services at the right time and at the right place to support their business functions. The main goal of these processes is to ensure that the ICT services are provided according to the agreements with the business, to achieve a stable services provision and to provide support to the users in case of service disruptions. This includes responding to the needed changes and reacting to failures in ICT services provision. An important development reflected in the Service Support book is the transformation of the IT Help Desk into a broader IT Service Desk, which has taken place in many organizations. The processes covered by this book aim at achieving short-term goals for the ICT management organization and can be found on the operational level on fig. 2.5. These processes are (CCTA, 2000):

- *Service Desk* – the function of the service desk is to provide a point of contact between the users and the providers of ICT services, which include the organization's own ICT department and third-party support organizations. It is the focal point for reporting incidents and making service requests. The main goal of the service desk is to ensure the long-term customer satisfaction and help in optimizing and lowering the costs of ownership and ICT service production by efficient use of resources and technology, supporting of the integration and management of change across businesses and process boundaries in the organization, and by identifying business opportunities. The service desk is a further development of the Help Desk described in the Service Support set of ITIL. Next to handling incidents, problems and questions, the service desk provides also interface for other customer requests, e.g., requests with regard to changes, service level management, availability and configuration management, financial management. An important function of the service desk is to keep users informed of the progress in the resolution of their incidents and problems, and provide them with information on events and actions that are likely to impact service levels.

- *Incident Management* – the main goal of incident management is to handle and resolve incidents in order to minimize their impact on the ICT services production and restore normal service levels as quickly as possible. An incident is considered to be any event, which is not a part of the standard operation of a service and causes, or may cause, an interruption to, or a reduction in, the quality of that service. The incident management process is responsible for diagnosing the incident and resolving it, if possible, or sending it for further support otherwise. The emphasis here is laid on restoring the service within the shortest time frame and procedures for known errors and workarounds are used to accomplish this. Escalation is performed in case of critical incidents, or if the escalation threshold for an incident has been exceeded. Incident priorities and escalation procedures are normally agreed as part of the SLA's. The documenting of and reporting on incidents are also part of the responsibilities of the incident management process. Incident management has close interaction with the service desk, as well as with the problem management and change management processes described below.

- *Problem Management* – the main goal of Problem management is to minimize the negative impact of errors in the ICT infrastructure on the service levels, and to prevent recurrence of incidents related to these errors. In order to achieve this, problem management seeks to identify the root cause of an error, and then take corrective actions to improve the situation. This process has two aspects: reactive, when actions are taken to resolve one or more incidents, and proactive, when actions are taken to prevent these incidents from occurring in the first place. The emphasis within problem management is laid on detecting the underlying causes of an error, and their subsequent resolution and prevention, unlike incident management, where procedures and workarounds are used to restore the service as soon as possible, rather than searching for a permanent resolution. The control over the resolution of an error, the analysis and identification of trends, carrying out problem reviews and reporting on problems are activities, which also fall within the scope of problem management.
- *Configuration Management* – the main goal of configuration management is to account for and provide accurate information about the ICT assets of the organization and their configuration. Configuration management provides a logical model of the ICT infrastructure and services of the organization, by means of which information about the versions of the existing configuration items (CI's) is identified, controlled, maintained and verified. This includes the identification, recording and reporting of the versions, constituent components and relationships of hardware and software items and the associated documentation. The information, provided by configuration management enhances the control of these items and increases the efficiency of making changes and modifications. Configuration management is an integral part of all other service management processes. It has a particularly strong relationship with Incident and Problem Management, as well as with the processes of Change Management and Release Management described below.
- *Change Management* – the main goal of change management is to ensure the timely and efficient handling of all changes to the ICT infrastructure of the organization, and to minimize the impact of change-related disturbances on the quality level of ICT services. An important aspect of achieving this goal is the use of standardized methods and procedures for assessing the risk, determining the impact, and implementing changes. The Change Management process comprises a number of steps, which have to be carried out in order to maintain a proper balance between the need for a change and its impact. These steps include the receiving of a change request, followed by a careful analysis of the impact of the change and the risk to business continuity, determination of necessary resources and approval of the change. The management and coordination of change implementation, as well as reporting on changes are also part of this process. The scope of change management includes all hardware and software components of the ICT infrastructure of the organization, as well as the documentation and procedures, associated with them. Change management works very closely together with configuration and problem management, and has strong relationships with the release management process discussed below.
- *Release Management* – the main goals of release management are to plan and oversee the successful changes and the secure and traceable rollout of hardware and software, to design and implement efficient procedures for the rollout, to agree the content and rollout

plan for the release, and to communicate and manage customer expectations throughout the planning and rollout of new releases. It focuses on the protection of the live environment and its services through the use of formal procedures and checks, and is essential to the successful packaging and distribution of releases to the customer. The scope of release management comprises the planning, design, build, configuration and testing of hardware and software to create a set of release components for the live environment. It also covers the planning, preparation and scheduling of the rollout of a release. The main components controlled by release management are the application and system software (developed both in-house or externally), the hardware components of the ICT infrastructure, and the documentation associated with them, including user manuals. Release management works closely with change management and configuration management in order to ensure that the configuration information is kept up-to-date following changes implemented by new releases, and that the content of those releases is also properly documented and included in the configuration information.

The books, covering the other three basic elements of the restructured ITIL are still under development. The topics, which they will cover, can be summarized as follows:

- *The Business Perspective* - this book will comprise a number of topics, which are related to understanding and improving ICT services provision as an integral part of the overall business management of the organization. These topics include: customer liaison, managing facilities management (outsourcing of ICT services), managing supplier relationships, third party and single source management, understanding and improving IT service management, surviving IT infrastructure transitions;
- *IT Infrastructure Management* - this book will cover six topics, which are related to the operations management. These topics are: network services management, operations management, management of local processors, computer installation and acceptance, systems management, environmental management;
- *Applications management* - this book will deal with the relation between management and the lifecycle of software development. The main goal of applications management is to deal with the changes in the business, and ensure that the requirements of the business are clearly defined, and the implemented solutions correspond to the needs of the clients. This book will cover the topics software lifecycle support and testing an IT service for operational use.

2.2.3. Other approaches

A number of other ICT management approaches have been developed over the years (Frenzel, 1996; Uijttenbroek et al, 1999; Van Herwaarden and Grift, 2002; Pols and Meijer, 2002; Outvorst, 2002; Ruijs and Schotanus, 2002; Drake, 2002, Hertroys et al, 2002). These approaches address different (combinations of) aspects of ICT management, which vary from application management, to functional management, to network and operations management, to the overall management of the information resources and the alignment of the ICT and business strategies in the organization. Although often using a different terminology, most of them cover a subset of the topics covered by ITIL and MCM, expanding and elaborating on the contents and/or relationships among specific processes, or trying to build implementation models on the elements, provided by these two approaches. Due to the fact that these approaches lack the comprehensiveness of ITIL and MCM their application is limited, however, their value can be seen in the fact that they are complementary to the latter two with regards to specific aspects and issues in ICT management. Three of these approaches, which provide a significant contribution in this respect, are shortly described below.

The *HP IT Service Management Reference Model* (Verheul et al, 1998; van Zanten, 1999; Drake, 2002) developed at Hewlett-Packard aims at providing a framework for presenting and describing the IT management processes, their interrelationships and business linkages necessary for the successful development, deployment and support of ICT services. This model incorporates many of the ITIL processes described above and adds several new ones, which are related to the more business-like operation of ICT within an organization. According to the model, the ICT service management processes can be divided into five process groups: *Business-IT alignment* covering the business assessment, ICT strategy development and customer management processes; *Service design and management* covering the service planning, service level management, security management, availability management, capacity management and cost management; *Service development and deployment* covering the build and test and release to production processes; *Operations bridge* covering operations management, incident management and problem management; and *Service delivery Assurance* covering configuration management and change management. The model aims at providing a high-level guidance on the general flow of activities during the entire lifecycle of ICT services management.

The *Information Technology Process Model (ITPM)* developed at IBM Global Services (Hertroys et al, 2002) is a reference model for controlling ICT within an organization. It aims at providing a starting point for understanding the current processes and forming a basis for their design and restructuring. It can be also used as an assessment system for determining the strengths and weaknesses of the ICT organization. The model describes a set of ICT processes and their constituent activities, and shows the information flow between the activities and processes. However, this is not an implementation model and does not provide a set of instructions that have to be followed, which contributes to its flexibility and easy adaptation in different situations. The model aims rather at providing a framework within which the best practices described in ITIL should be implemented. In this way, ITPM can be used as a complementary model to ITIL.

The *Microsoft Operations Framework* (MOF) is Microsoft's vision for ICT service management (Pultorak, 2002). It is a guidance for managing production systems, and is an extension of the best practices described in ITIL, providing guidance specific to Microsoft products and technologies. MOF is a collection of principles, best practices and models, and aims at providing a *"comprehensive technical guidance for achieving mission-critical production system reliability, availability, supportability, and manageability for solutions and services built on Microsoft's products and technologies" (Microsoft, 2001).* MOF consists of three core models – process, team and risk. The *process model* is a functional model of the processes that operations teams need to perform in order to manage and maintain ICT services. It covers the processes described in the Service Delivery and the Service Support books of ITIL, and complements them with Microsoft-specific operational processes. The *team model* aims at organizing and coordinating the work of the different teams engaged in operational activity. It describes the roles of these teams, their relationships, and communication, and provides guidelines about how they can be implemented in an organization. The *risk model* aims at providing a framework for managing the risks in an operational environment. It applies proven risk management techniques to the daily operational problems, customized for application especially in software development and deployment projects. The added value of MOF can be seen in that it complements ITIL by providing more prescriptive versus descriptive guidance with regards to the implementation of especially operational processes.

2.2.4. Concluding remarks

The approaches, presented above offer a number of advantages to the practitioners involved in the daily ICT management. They offer a frame of reference with regards to the structure of the ICT organization, the resources, the tasks and the processes that have to be carried out, the interrelationships, and the communication and coordination necessary for achieving an effective and efficient ICT management. Some of the approaches provide also guidelines with regards to the practical implementation of ICT management. In this way, they can be used as a tool for improving existing ICT management processes, and for planning and implementing new ones. They also help for building a well-structured vision in the organization about the way in which the management of ICT should be organized.

MCM and ITIL offer overall frameworks for organizing the management of ICT, and provide a detailed description of ICT management tasks and processes and their structure and interdependencies. They can be used to grasp critical IT characteristics and process interrelationships, and form a sound basis for initiating an organizational change within ICT. Most of the other approaches cover a limited subset of these tasks and processes, and focus on specific aspects of their implementation.

However, there are also a number of issues that have to be addressed when applying these approaches in practice. They represent mostly frameworks for the management of ICT, which are rather process maps than organizational models, and lack a structure for modeling and application (van Bon, 2002). The actual application of the approaches in practice and the implementation aspects form a relative void in the literature. The approaches offer few guidelines as to how the processes can be implemented in the organization, and/or how the organization has to change (reengineer) its structure to accommodate the processes. This leaves many “how-to” questions unanswered (Bootsma and van Bon, 2002), although practical approaches to overcome this are emerging (Looijen and De Jong, 2002). An important issue is their inability to predict organizational structures in detail, which leads to a gap between approach and practice (De Jong, 1996; Bootsma and van Bon, 2002). Scalability is yet another issue – it is not immediately clear how much of a process a small organization should implement and which tasks and activities should be left out.

To summarize, based on the information presented above, as well as on the personal views and experience of the author, it can be concluded that the ICT management approaches offer visions about the management of ICT and provide the necessary constituent elements, but leave open the questions related to their implementation in practice.

2.3. Business Process Reengineering

As indicated in the previous section, there are a number of issues, which have to be resolved when implementing a certain ICT management approach in practice and making changes to the existing ICT management processes or setting up new ones. Business process reengineering (BPR) can be used for coping with these issues, and carry out the process change in a well-structured and coordinated manner. The following sections offer information about the goals of BPR, the methodologies, techniques and tools used in it, and its advantages and disadvantages.

2.3.1. Background information

The environment, in which contemporary organizations operate, is becoming increasingly dynamic and competitive, and undergoes unprecedented changes (Knoll and Jarvenpaa, 1994; Quinn, 1992; Davenport, 1993, Kettinger et al, 1997). Although there are a number of factors, which contribute to this (Parker, 1996; Benjamin and Blunt, 1992), Information Communication Technology (ICT) is seen by many as the major one (Davenport 1993, Parker 1996, Davenport and Short, 1990; Broadbent et al, 1999; Benamati and Lederer, 2001), being both critical to creating products and delivering services, and an enabling factor for business strategy execution. In order for organizations to stay competitive in the changing environment and capitalize on the developments in ICT, there is a growing need for a radical change in the way in which they operate (Hammer, 1990, Hammer and Champy, 1993).

Business process reengineering (BPR) (Hammer and Champy, 1993) offers a structured approach for managing this change. It has quickly become, and remains, a very popular approach to organizational improvement (Jones, 1994). Known also as business process redesign (Earl, 1994), business process innovation (Davenport), or business process improvement (Harrington), BPR is building on the principle that organizational activities have to be organized around processes rather than functions, which will generate major improvements in terms of organizational effectives and efficiency. This in its turn will increase customer satisfaction and give the organization a competitive advantage (Hammer, 1990; Davenport and Short, 1990; Hammer and Champy, 1993). Defined by its founder Hammer (1993) as the *'fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service and speed'*, BPR in its essence represents a planned, rational and phased approach to the management of organizational change (Swan et al, 1998), which aims at yielding sustainable improvements in profitability, productivity, service and quality (Archer and Bowker, 1995). The timely and proper use of ICT is generally seen as an integral part and a critical success factor for the BPR endeavor (Earl, 1994; Donovan, 1994; Homa, 1995; Al-Mashari and Zairi, 2000).

2.3.2. BPR and ICT

ICT and BPR are closely interlinked (Wastell et al, 1994) and their relationships and interdependencies have been studied and discussed by many researchers and practitioners. Most of them see ICT as the driving force behind BPR (Davenport and Short, 1990), a major tool and a fundamental enabler (Hammer, 1990; Davenport, 1993; Jones, 1994; Hammer and Champy, 1993, Venkatraman, 1994), and argue that IT is a major component of most BPR projects, e.g. by installing new hardware and software, and using systems analysis and modeling tools (Teng et al, 1994). According to Hammer (1990), modern ICT plays a major role in supporting and enabling BPR implementation. Davenport (1993) distinguishes among several types of organizational impacts of ICT-enabled BPR, among which automational, informational, sequential, analytical, geographical, integrative and intellectual.

Childe et al (1996) distinguish between two main groups of ICT applications in BPR: change technologies and support technologies. *Change technologies* refer to the use of ICT for analyzing existing process orientations and assessing their effectiveness and efficiency, which involves process modeling and performance measurement analysis. *Support technologies* refer to the implementation of information systems to support the required process configurations, with a strong emphasis on allowing and facilitating their continuous improvement and change.

The relationships between ICT and BPR are described by Davenport and Short (1990) as a recursive loop, in which they continuously refine each other. This view is also supported in Al-Mashari et al (2001), where the ICT and organizational infrastructure are described as mutually evolving and influencing each other. The achievement of dramatic improvement of performance by using ICT involves altering certain characteristics of the business processes (Teng et al, 1994), which are related to how functions are coupled together and coordinated. This applies also to the ICT management processes in the organization (Albers et al, 1994), which need to be changed to respond to the changing technology and increase their effectiveness and efficiency. Hammer (1990) and Venkatraman (1994) point out that the biggest advantage of ICT can be attained by using it for creating new effective business processes, rather than simply automating the old ones.

ICT can be used to reshape the business processes by facilitating the information flow between globally distributed processes and ensures the availability of instantaneous and consistent information across the business (Klenke, 1994; Al-Mashari and Zairi, 2000). It can provide new opportunities for process redesign by improving communication and coordination of activities, relaxing constraints on where work is done, facilitating integration and interconnection of workers, and providing new ways for encoding and sharing a firm's knowledge (Turner, 1998). In this way the degree of mediation in the organization can be reduced and the collaboration enhanced (Teng et al, 1994), making it possible to replace the traditional hierarchy as the primary method of transmitting information in the organization (Turner, 1998), and advance towards creating a networked organization. All this gives ICT a major role in the reengineering of business processes, the importance of which, according to Hammer and Champy (1993), "is difficult to overstate".

2.3.3. Methodologies, Techniques and Tools for BPR

A number of methodologies and approaches have been developed over time for carrying out BPR (Klein, 1994; Wastell et al, 1994; Jacobson et al, 1995; Choi and Chan, 1997; Vakola and Rezgui, 2000; Al-Mashari and Zairi, 2000), but it is still considered to be more "art than science" (Davenport, 1993). However, there are a number of components, which are essential to the success of the BPR endeavor. They cover the thorough examination of the current business processes in order to identify bottlenecks and non-value-added activities, the identification of improvement opportunities, the design of the new processes and the necessary IT to enable/support the reengineering endeavor, the actual implementation of the new processes and the evaluation of the achieved results. These components are captured in a framework, which is described in (Kettinger et al, 1997) and consists of the following stages:

- *Envision* – consists of establishing management commitment and vision for the BPR endeavor, discovering reengineering opportunities within the organization, identifying the

ICT levers, which will enable/support the reengineering, and selecting the processes, which will be reengineered;

- *Initiate* – consists of informing stakeholders about the planned reengineering, organizing the reengineering teams, which will participate, conducting project planning for the reengineering project, determining the requirements of external process clients, and setting the performance goals of the reengineering endeavor;
- *Diagnose* – covers the documentation of the existing processes in terms of activities, resources, communication, roles, ICT and costs, and analyzing them in order to discover bottlenecks, problems and non-value-adding activities in their internal working, as well as in their interdependencies and interactions with other processes;
- *Redesign* – consists of defining and analyzing the concepts of the new processes, devising and comparing process alternatives, creating prototypes and detailed designs of these processes, designing the human resource structure of the processes and the way in which they will be implemented in the organization, and analyzing and designing the information system(s) necessary to support the reengineered processes;
- *Reconstruct* – covers the actual implementation of the new processes and the migration to the new process responsibilities and human resource roles. The IT platforms and systems necessary to support the new processes are implemented, and the users are trained to work with them.
- *Evaluate* – in this stage monitoring is carried out to determine the performance of the new processes against the defined goals. This is often carried out in close relation to the continuous total quality improvement programs in the organization.

The growing popularity of BPR has lead to the development of a large number of techniques and tools that are used to support it (Klein, 1994, Kettinger et al, 1997). In this context, a technique is defined as "*a set of precisely described procedures for achieving a standard task*", and a tool as "*a computer software package to support one or more techniques*" (Kettinger et al, 1997).

Various *techniques* are employed during the different stages of a BPR endeavor, and their choice depends on the goals of the stage, as well as on the specific characteristics of the reengineered processes in the different organizations. The tools, on the other hand, are used to facilitate the use of a specific technique and increase its effectiveness and efficiency. A number of surveys and classifications of BPR techniques and tools have been published (Klein, 1994; Kettinger et al, 1997; Yu and Wright, 1997; Al-Mashari and Zairi, 2001), aiming at providing a framework for mapping techniques and tools to the different BPR stages, and providing a set of criteria for selecting techniques and tools for a specific BPR project. An extensive list of BPR techniques is provided in (Kettinger et al, 1997), which indicates that at least 72 different techniques are used. These techniques are divided in eleven categories, which include business planning, organizational analysis, project management, process modeling, change management, creative thinking, customer requirements analysis, analysis and design of information systems, process measurement, problem diagnosis and solving, and process prototyping and simulation.

A significant place within BPR techniques is taken by process modeling techniques which are increasingly used for analyzing, supporting and optimizing business processes. Among the most important of these techniques are *Petri Nets* (e.g., Reisig, 1992), which are gaining popularity as a tool for the modeling, analysis and verification of business processes. The advantages of Petri Nets for process modeling include (van der Aalst, 1997; Janssens et al, 1998) their formal semantics, graphical nature and expressiveness, their capability to explicitly model the state of the process, as well as the availability of many analysis techniques which can be used to prove process properties and calculate process characteristics. In their original form Petri Nets have also a number of disadvantages, e.g., the tendency to grow very large even for processes with middle complexity and the lack of means for representing time and data. Therefore, a number of enhancements to the classical Petri Nets have been suggested, which include the introduction of high-level Petri Nets and the addition of color (Jensen, 1992), as well as the introduction of time into the Petri Net (Haas, 2002). These enhancements make Petri Nets one of the most viable techniques for process modeling and analysis.

A popular application of Petri Nets for process modeling is their use in the area of *workflow management* (van der Aalst, 1998). The main goal of workflow management (van der Aalst, 1997; van Hee and van der Aalst, 1997; Grefen, 2000) is to ensure that the right person carries out the right work at the right time and with the right resources. In order to achieve that, different workflow management systems (WFMS) are used, a WFMS being a system that defines, manages and executes workflows based on a computer representation of the workflow logic. In this context, Petri Nets are a convenient tool for achieving a formal representation of this logic, which is suitable for further analysis, verification and implementation in a computer program.

The *tools* used in BPR consist of a number of software applications, which automate the use of the BPR techniques, and aim at achieving improved productivity (Klein, 1994), finishing projects faster (Kettigner et al, 1997), producing higher quality work and eliminating non-value-added activities (Al-Mashari and Zairi, 2000). The tools are extensively used during all stages of a BPR project and are critical to its success. A number of essential features for BPR tools have been defined (Davenport, 1993; Klein, 1994; Im et al, 1999), which can be summarized as follows:

- ability for use by non-technical people;
- enhancing the clarity of the BPR team's vision;
- enforcing consistency in the process analysis and design;
- permitting an iterative and top-down refinement of a BPR project goal to its solution;
- producing an acceptable return on investment;
- ability to provide interactive and graphical-based demonstrations of process phases;
- ability to show information flows between phases and the rates of flows and resource uses;
- ability to run live simulations to discover bottlenecks and constraints;
- ability for integration with CASE tools used for designing the supporting information systems.

Many different tools are currently used in BPR (Kettinger et al, 1997, Im et al, 1997; Yu and Wright, 1997). In (Kettinger et al, 1997) 102 different tools are identified, which are used for achieving various goals throughout the BPR endeavor. The choice of specific tools depends on the specific goals of the BPR project, the type of the reengineered processes, the adopted methodology, the budget and timeline of the project, the cost/benefit ratio, as well as the available expertise for working with the tools. According to Klein (1994), the existing tools can be classified into the following six groups based on their role in BPR projects:

- project management tools (e.g., Microsoft Project, Harvard Project Manager);
- coordination tools (e.g., e-mail, MS Excel, Word Perfect Ofiice);
- modeling tools;
- business process analysis tools;
- human resources analysis and design tools;
- system development tools.

A number of issues have been identified with regards to the tools used in BPR. These issues include ease of learning and use, ability to integrate with other tools and a cost/benefit ratio appropriate for the specific BPR project (Klein, 1994), capturing process dynamics (Franken and de Weger, 1997), process visualization and multimedia features (Im et al, 1997, Kettinger et al, 1997). These issues should be taken into account when choosing the tools for a specific BPR project, and are considered critical to the successful use of the tools.

2.3.4. Concluding remarks on BPR

As organizations strive to function and perform in today's highly dynamic, competitive and increasingly global environment, changing the business processes of the organization and adapting them to the new conditions is receiving growing attention as a mechanism for improving their effectiveness and efficiency. Business process reengineering provides a solid, well-structured framework for managing this change. It offers a collection of methodologies, techniques and approaches for changing business processes, relying heavily on Information Communication Technology as the driving force and the enabler of this change. However, it raises a number of issues when it comes to the actual implementation of the new or reengineered processes. These issues are related mostly to the way in which the processes have to be implemented in the organization, estimation of the impact and the benefits of the process changes, the distribution of tasks and their coordination, and the prediction of bottlenecks and problems associated with the processes. There is still a scarcity of suitable models and frameworks that address these issues (Al-Mashari et al, 2001), however, resolving them is of critical importance for the success of the BPR endeavor.

A large number of tools are used in all stages of BPR. These tools support the techniques chosen for a specific BPR project, and aim at automating the activities that need to be carried out, and at improving their productivity and the quality of the achieved results. However, there is still a lack of tools, which address the issues mentioned above and more theoretical and practical research is needed to develop them. Among the essential features defined for such tools are facilities for process visualization, ability to capture the stochastic and dynamic character of the business processes and their complex interrelationships, as well as abilities to run live simulations of the processes.

2.4. Discrete-Event Simulation

Until recently, discrete event simulation was used as a tool for modeling complex systems mostly in the fields of manufacturing and the exact sciences. However, new developments in the field of simulation, e.g., animation, object-orientation and abilities for integration with other software tools make it possible to expand its areas of application to include fields like management, social systems and business processes. The following sections provide more information about discrete-event simulation, its most important features, and its application in the area of business process reengineering.

2.4.1. Overview of Simulation

In the following paragraphs a concise overview of simulation, its characteristics, capabilities and application is provided. The discussion focuses on three main points: basic simulation concepts, the stages of building and using a simulation model, and the use of animation in simulation models.

Basic Concepts

According to the *Webster's Collegiate Dictionary* to simulate means "to feign, to obtain the essence of, without the reality". In line with this definition, it can be said that simulation aims at building a model of a real system, which possesses a set of essential characteristics of the system and imitates certain aspects of its behavior. This model is called *simulation model* and can be used for exploration and experimentation in order to get insight into the qualities and behavior of the real system without having to experiment with the system itself. This can be achieved by studying the reaction of the model to different events coming from its environment, and can be used for answering "what if…?" questions about the system (Pidd, 1996). According to Schriber (1987) simulation involves the modeling of a process or system in such a way that the model mimics the response of the actual system to events that take place over time. Shannon (1975) and Pegden et al. (1995) define simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system. The basic idea behind simulation is simple (Giaglis, 1999): we wish to acquire knowledge regarding a real-world system, but the system is not easy to study directly. We therefore proceed indirectly by creating and studying another entity (the simulation model), which is sufficiently similar to the real-world system, so that we are confident that some of what we learn about the model, will also be true about the system. Based on the information obtained during experimentation with the model, informed decisions can be reached regarding the system.

Depending on the simulated real system, the means used to conduct the simulation, and the used simulation approaches, simulation can be divided into several types. For the purposes of the present research, we are particularly interested in *computer simulation*, i.e., simulation, which is carried out on a digital computer, and where the model is a computer program. Fishwick (1995) defines computer simulation as "the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analyzing the execution output". Simon (1973) states that one of the most important uses of computers is “to model complex situations and to infer the consequences of alternative decisions to overcome bounded human rationality”.

A very important feature of simulation is the possibility to build *dynamic* models of systems, that is, models, that describe the behavior of a system through time (as a function of time), as opposed to *static* models, which describe the behavior of a system at a single point in time. In this way, the dynamic characteristics of the system can be captured and studied in a simulation model, which is seen by many authors as one of the greatest benefits of simulation (Ingalls, 2001; Berends and Romme, 1999).

Another important feature of simulation is the possibility to build *stochastic* models of systems. A stochastic model is a model, which uses some kind of probabilistic distribution to generate the values for the model variables (Berends and Romme, 1999) and explicitly tries to capture the randomness in the behavior of the system, as opposed to a *deterministic* model, which fixes the values of model parameters and ignores this randomness, assuming it to be unimportant to the decision to be made. Randomness is an intrinsic characteristic of most real-life systems and including it in a simulation model allows for modeling uncertainties and complexities of system behavior, which increases the accuracy and validity of the model.

For the purposes of modeling and simulation ICT management processes can be viewed as discrete-event systems. These are systems, whose state changes occur in discrete points in time and are driven by inputs to the system, called discrete *events* (Pegden et al., 1995; Arsham, 1997; Nidumolu, 1998). As Arsham (1997) points out, for most discrete event systems no analytical methods are available, so they have to be studied using simulation. In discrete-event simulation the state of the model changes only at discrete, possibly random set of simulated time points (Schriber and Brunner, 1998) and is initiated by the occurrence of *model events*. It is also possible to model the simultaneous occurrence of events in the system and the parallel movement of entities and their competition for a specific resource in the model. In this way, discrete-event simulation offers a very good method for modeling the people and equipment as resources in the model, the information exchanged among them as entities moving simultaneously in the model and competing for system resources, and the events changing the state of the processes as model events. Throughout the rest of this book we will use the term *simulation* synonymously with *discrete event computer simulation*.

Stages in Building and Using a Simulation Model

The building of a simulation model of a real system goes through a number of stages (Pegden et al, 1995; Shannon, 1998; Banks, 1999; Law and Kelton, 2000; Pritsker et al, 1997; Law and McComas, 2001). These stages can be summarized as follows:

- *Problem definition and planning* – in this stage the goals of the simulation study are defined. This is of critical importance to the success of the simulation endeavor. It involves the gathering of information about the problem and translating this information into questions that have to be answered during the simulation study. Decisions are made in this stage with regards to the information necessary to carry out the study, the ways to gather this information, the criteria that will be used to assess the results of the study, and the parties involved in the study. The stage also includes the planning for the resources necessary to complete the study, the steps that have to be taken, as well as the timeline of the study.

- *System definition and conceptual modeling* – in this stage the boundaries and restrictions, which will be used for specifying the system and the way it works are defined. This is achieved by defining a subset of system characteristics relevant to the goals of the study, which will be sufficient for achieving these goals. This subset should, on the one hand, be big enough so that the system is not oversimplified, which could lead to trivial and/or misleading modeling results, and on the other hand, it should not carry too much detail, which could make the system clumsy and/or prohibitively expensive to build and run. Based on the chosen system characteristics a conceptual model of the system is built. This model forms the basis for building the simulation model (Frantz, 1995) and is used to provide a representation facilitating the understanding of a real world context, situation or object (Haddix, 2000). It describes the components that have to be included in the simulation model, their functionality, characteristics and interactions. This includes dividing the modeled system into logical subsystems, defining the entities that will flow through the system, the rules guiding this flow, the places where the entities change their state, as well as the alternative system designs which have to be considered.

- *Gathering input data* – consists of identifying and gathering the input data for the model, selecting the measures of effectiveness to be used, the factors to be varied, the levels of those factors which will be included in the investigation, as well as how many samples will be needed to carry out the experiments. This influences to a great extent the design of the simulation model. Stochastic systems contain numerous sources of randomness, and the input data should be chosen carefully, so that it captures this randomness. Decisions have to be made with regards to the data to be collected, whether it is readily available and pertinent, whether it is valid for the required purpose (goals of the study), the ways in which to collect it, and the necessary tools. The possible data sources and the potential problems associated with them should be studied (Brately et al, 1987; Pegden et al, 1995), as well as the possible inaccuracies in the model introduced during the data gathering process (Robinson, 1999). In case historical data about the system does not exist certain assumptions based upon theoretical considerations, and estimations of the probability distribution and parameters of the data have to be made (Law and Kelton, 2000; Pegden et al, 1995). An important activity carried out at this phase is processing the gathered raw input data so that it is suitable for use in a simulation model. This includes sampling directly from empirical data, fitting data to theoretical distributions and sampling from these distributions by using random variable generation.

- *Model development* – consists of building the computer program that represents the model and will be used for carrying out the simulation experiments. The model can be built using a general-purpose programming language, a general-purpose simulation language, or a special-purpose simulation language. However, the last two offer distinct advantages in terms of ease of use, effectiveness and efficiency. Many contemporary simulation languages are integrated into simulation packages, which follow two basic concepts (Oren and Zeigler, 1979): 1) separation of experiment specification, modeling and output analysis, and 2) using the current computer capabilities for database management, graphics and program verification. These packages offer a number of advantages to the simulation modeler, among which reduced programming risk and fewer errors, guidance with regards to bridging the gap between the users' conceptual representation of the model and its machine implementation, flexibility and ease in model modification, enhanced animation facilities, tools for processing and analyzing input and output data.

- *Model verification and validation* – in this stage actions are taken to ensure that the model operates the way it was intended to. A distinction can be made between two different aspects. *Verification* is carried out to ensure that the implementation of the computerized model of the system is correct (Sargent, 1994), and deals mainly with building the model right (Balci, 1998). It involves debugging and code examination to ensure that the conceptual model of the system is accurately translated into an executable computer model, and that all parts of the model work and interact correctly and use the right data at the right time (Pegden et al, 1995; Shannon, 1998). *Validation*, on the other hand, ensures that the results of the models are correct (Sargent, 2000) and that the model is a valid representation of the real-world system being modeled (Pegden et al, 1995), taking into account its domain of applicability and intended application (Schlesinger et al, 1979). Validation should always be carried out against the set of objectives for which the simulation model is developed (Law and McComas, 2001) and aims at building an acceptable level of user confidence that the model adequately represents the real-world system and that the inferences about it drawn from the model are correct (Shannon, 1998). Numerous techniques are used to establish the validity of a simulation model varying from examining flow charts of the modeled processes, to studying animated models of the work of the system, to comparing model outputs to historical data and real-system outputs. An extensive overview of these techniques is provided in (Sargent, 1994).

- *Experimentation with the model* – consists of designing and carrying out the experimentation runs with the simulation model, and gathering and storing the generated data. Two main activities are carried out at this stage: experimental design and the actual experimentation with the model. The experimental design takes care that the use of the model and the necessary resources are carefully planned **(**Cook 1992, Hood and Welch 1992, Nelson 1992, Swain and Farrington 1994, Kelton 1995, Shannon 1998). It also ensures that the different scenarios to be simulated are defined, and that for each scenario the length of the run, the number of runs (replications) and the initialization are planned (Banks, 1999; Law, 2000). The actual experimentation with the model consists of carrying out the planned simulation runs. Issues that have to be addressed here are whether the system is terminating or non-terminating, definition of starting conditions, and determining whether additional simulation scenarios and/or runs are necessary. Care has to be taken that the generated output data are captured and stored in the proper format. It should be noted that, due to the fact that simulation is an iterative process, in this stage changes and/or improvements to the original model can be initiated. Depending on their size and impact a transition back to the stages *Model development* and *Model verification and validation* may be necessary.

- *Analysis and interpretation* – in this stage the output data generated by the model are analyzed and interpreted taking into account the objectives of the simulation study. Issues addressed here are, e.g., whether correlation of output data exists or which statistical tests are valid on the data (Pegden et al, 1995; Shannon, 1998). If correlation exists, actions have to be taken to ensure that data points are independent before proceeding with the analysis (Law and Kelton 2000, Shannon 1998, Kelton, 1996). Based on the output data, the performance of the simulated system is assessed, and alternative system configurations are compared. The modeling assumptions, the results of the study and possible recommendations are documented and presented to the user, highlighting the issues considered important by the user.

Animation

The use of animation is a comparatively recent development in the world of simulation modeling, but has nevertheless proved to be an increasingly important tool for gaining insight into the working and internal dependencies of the simulated system, verifying and validating simulation models, and communicating the results of a simulation study to the involved parties (Pegden et al, 1995; de Vreede and Verbraeck, 1996, Law and McComas, 2001). According to a recent survey (Hlupic, 1999) the presence of good animation facilities is one of the main positive features of simulation software, and animation is seen as one of the reasons for the increased use of simulation in recent years (Law and Kelton, 2000). According to (Pegden et al, 1995) animation generates a moving picture of model operation and in this way brings the model to life, which can provide valuable insights into the model behavior, which are not easily obtained by using statistical methods. Animation can be used to achieve close resemblance between the outlook of the model and the simulated system and its environment, which can direct and restrict the novel ideas created by the model (Smeds, 1997). This dynamic representation of the model behavior offers a number of benefits, which can be summarized as follows:

- *Model verification* – animating the movement of entities within a simulation model is a very good tool for identifying errors in the logic of the model. Animation provides a very effective way to gain insight into the interaction of system components. Entities going to the wrong place in the model, using the wrong resources, as well as resources performing the wrong operations can very easily be identified by watching the model execution. This speeds up and increases the effectiveness and efficiency of the model debugging process, and reduces the likelihood of undetected errors (Pegden et al, 1995; Law and Kelton, 2000).
- *Model validation* – through animating the model behavior, the changes to the state of the modeled system can be interactively viewed during model validation. Moreover, using dynamic graphical plots and animations of the model output data gives the people involved in validation quantitative information about the working of the model, which helps to establish the operational model validity (Sargent, 1996). Animation can be used for communicating the way in which the model operates to people which are experts on the system under investigation, but have little or no knowledge of simulation (Pegden et al, 1995), thus enabling them to participate in the model validation process and increase its effectiveness and credibility. This can greatly enhance the understanding and assessing of the impact of model reductions (simplifications), identify inconsistencies, and determine the validity of the simulation model.
- *Model use* – animating the operation of a model can be very useful when the model is used for determining system performance and comparing system design alternatives. By visualizing the interactions of model components, elements and/or processes can be identified, which limit the performance, and which are often not obvious from statistical analysis and graphical plots of output data, and possible improvements to the system design can be suggested and tested in order to eliminate them (Pegden et al, 1995). Animated interactive simulation models can also be used in brainstorm sessions for generating and testing new ideas, and informed decisions can be made on the basis of the model results (Currie and Hlupic, 2000).
- *Model results communication* – animation is a valuable tool for communicating the results of a simulation study to the involved parties. Animation facilitates the understanding of model operation (Pegden, 1995), and consequently – the understanding of model results. The acceptance of these results for use in the decision-making process depends on their understanding and perceived credibility, which is strongly related to their effective communication. Animation provides effective communication of the model results, and is thus closely related to their credibility (Johnson and Poorte, 1988, Law and McComas, 2001). It can be also used for promoting communication with the

people involved in the system under investigation (Grant and Weiner, 1986), as well as within the simulation team (Verbraeck and de Vreede, 1993; de Vreede and Verbraeck, 1996; Law and Kelton, 2000), thus increasing the effectiveness and efficiency of the modeling endeavor.

2.4.2. Simulation as a tool for BPR

A comparatively recent development in the field of simulation is its use as a tool in BPR. A number of cases have been reported in the literature (e.g., Snowdown, 1996; Grosz, 1998; Dennis et al, 2000; Aksu, 2001; Greasley, 2000; Manzoni and Angehrn, 1998), in which simulation is used to model existing business processes, assess their efficiency and effectiveness, identify problems and bottlenecks, and assist in generating ideas about, and model possible ways to modify these processes in order to improve them. It has also been used for evaluating the effects of these modifications, compare different scenarios and choose the one with the greatest added value for a specific situation.

The increasing popularity of simulation as a tool for BPR is due to the advantages it offers for business process modeling. According to Tumay (1996) a business process simulation model can realistically capture the resource constraints, the decision rules and the stochastic behavior of real-world processes. Furthermore, such a model can capture the behavior of both human and technical resources in the process (Hlupic and Robinson, 1998). It can mimic the operation of the processes by stepping through the events in compressed time while displaying an animated picture of the workflow. The model output data gathered through the simulation can be used to evaluate the performance of the processes. According to Tumay (1995) simulation can be used to increase service level, reduce total process cycle time, increase throughput and reduce waiting time, inventory and activity costs. The advantages of simulation in comparison with other techniques used in BPR can be summarized as follows (Giaglis and Paul, 1996; Law and Kelton, 2000):

- *Facilities for modeling processes* – a process can be conveniently represented in a simulation model as a time-ordered set of interrelated events which modify the state of an entity, which closely corresponds to the concept of a business process as a ‘structured, measured set of activities designed to produce a specific output’ (Davenport, 1993).
- *Capabilities for modeling the dynamic and stochastic nature of business processes* – the cabilities to model the evolution of a process over time and take into account its stochastic characteristics are among the biggest advantages of simulation compared with other approaches which use static representation and deterministic models, and are considered to provide the greatest value for achieving BPR objectives (Tumay, 1995). These capabilities allow a simulation model to accurately mimic the dynamic and probabilistic behavior of real-life business processes and to capture the complexities associated with it, thus increasing the credibility and usability of model results.
- *Visual representation* – the animation of model operation together with the interactive depiction of key model performance indicators is a very powerful tool for gaining insight into the operation of the simulated processes, identifying bottlenecks and problems and generating ideas how to solve them, verifying and validating the simulation model, and communicating the simulation results to the involved parties.
- *Assessment and comparison of changes and alternatives* - a simulation model can easily be changed to represent different ways to organize a process, thus providing a low-cost

way for estimating the effect of proposed changes to the process and for evaluating alternative process scenarios.

- *Enhanced analysis and representation of results* – most of the contemporary simulation packages incorporate tools for analysis and representation of model data, which greatly enhances the reporting of and presentation of model results.

According to (Pritsker ,1992; Snowdown, 1996; Giaglis and Paul, 1996) simulation can have various functions and can be applied for achieving different purposes and at various levels and stages during the business process reengineering endeavor. The most important of these are listed below:

- *As an explanatory device* – a simulation model of a business process can be used to explain the way a process functions, understand the bottlenecks and problems associated with it, identify activities with little or no business value, and gain insight into (inter)process interactions. In this way it can help for developing process visions (Davenport, 1993) and for identifying processes and opportunities for reengineering.
- *As a communication vehicle* – an animated simulation model can help for describing and clarifying details about process or system operation, facilitating the communication among the members of a BPR team and communicate the (expected) results of the BPR to the involved parties. In this way it can help to streamline and improve the effectiveness and efficiency of the BPR endeavor.
- *As an analysis tool* – the capabilities of simulation to provide quantitative data and keep statistics about model operation make it possible to determine critical elements, components and issues in the processes under investigation and to estimate performance measures associated with them. In this way it can help to identify the levers, which can be used to change and implement the reengineered processes.
- *As a design assessor* – simulation can be used to evaluate proposed solutions on the basis of simulated performance measures, as well as to model and synthesize new alternative solutions. In this way it can help in the stage of designing and prototyping the reengineered processes.
- *As a training tool* – simulation can assist personnel in understanding business process operation, and can be used for acquiring knowledge about new or changed business processes, tasks or systems. This can facilitate the actual implementation of the reengineered processes and help to alleviate the problems and issues (e.g., resistance to change, lack of clarity about the functioning of the new processes, insufficient skills for carrying out the new tasks, sub-optimal process communication and interaction) accompanying it.

Next to the advantages it offers, the use of simulation in BPR gives also rise to a number of issues. Firstly, simulation has been traditionally used for modeling manufacturing processes, where the workflow is well-structured and the input and output of the process in many cases can be accurately measured, thus providing enough data to build and validate the simulation model. Business processes, however, contain a large amount of work carried out by people in office environments, which is characterized by many different types of loosely structured requests, relatively low repeatability (Mackey et al, 1996), which makes the gathering of data a complex and challenging task. Objective data collection may be difficult to achieve, and a trade-off between the structure and scope of a model and the availability of data may be necessary (Giaglis et al, 1999). Secondly, employees have great flexibility in the order and methods of carrying out tasks, which makes the processes more variable and less standardized than in a normal manufacturing process, and thus more difficult to capture in a formal model. Thirdly, there can be a high variability in processing times for the different requests, which impedes making assumptions about the stochastic distribution of the data to be used in the model. Fourthly, there is often a lack of historic data about the office processes, and the performance parameters associated with them are not easy to measure, which poses a challenge to the process modeler by leaving validation almost completely to the scrutiny of people involved in the processes and requiring subjective interpretation of the modeling results.

As explained above, simulation can be a very useful tool in BPR offering a number of advantages to the process modeler. Therefore, an increasing number of simulation packages include facilities for business process modeling and simulation, incorporating animation and intuitive graphical interfaces to facilitate the building and use of a model. However, simulation cannot offer an optimum solution (Tumay, 1996). Its strength is in capturing process dynamics and stochastic characteristics (Berends and Romme, 1999; Tumay, 1996; Manzoni and Angehrn, 1998). Simulating the different scenarios for a particular situation and choosing the best one taking into account the specific characteristics of the reengineered processes and the goals of the BPR endeavor can lead to achieving the optimum solution. It can also reduce the risks associated with BPR (Hlupic and Robinson, 1998) and increase its chance for success.

2.4.3. Concluding remarks on simulation

Discrete-event simulation is a powerful tool for modeling, studying and experimenting with complex systems, or systems with which direct experimentation is not feasible and/or possible. It offers a convenient way to capture and model system dynamics, randomness and the complex interdependencies, which often exist in real-world systems, and which cannot be modeled by using analytical tools or deterministic techniques. The recent developments in the filed of simulation and the increasing capabilities of simulation languages and packages allow for extending its area of application from the traditional fields of manufacturing and exact sciences to new ones such as management and the reengineering of business processes. The use of animation in a simulation model enhances to a great extent the work with the model, its verification and validation, and the use and communication of modeling results.

The use of simulation in business process reengineering offers a number of advantages in comparison with other tools currently used in this area. Simulation allows for the modeling of process dynamics, variability of activity times, interdependencies and other complexities affecting performance, and offers statistical input and output capabilities and advanced modeling elements that are necessary to accurately simulate business processes (Tumay, 1995). Using animation for simulating business processes facilitates to a great extent the understanding of the process operation, identifying bottlenecks and problems, generating ideas about ways to change the processes, and facilitate the communication throughout the BPR endeavor. According to Gladwin and Tumay (1994), the real payoff for simulation in the coming years will come from simulating business processes.

However, a number of issues have to be resolved in order to apply business process simulation successfully. Despite the big benefits of using simulation there is little awareness of its value (Giaglis et al, 1999), which limits its use as a tool for BPR. The data collection about and the formalization of activities involved in the business process is a very challenging task due to the high variability of inputs and processing times, the lack of historic data and the arbitrary choice of the sequence of activities to be carried out. Due to the fact that the use of simulation for BPR has started only recently, there are few established concepts and approaches, and this makes it difficult to build a conceptual model of the processes under investigation, define the exact steps that need to be taken, and assess and compare simulation results from different projects. There is also a need to create domain-specific libraries of simulation objects, which would allow for the reuse of modeling results and the reduction of model development time, and increase the reliability of the simulation models.

2.5. Conclusions

Although the MCM and ITIL offer solid overall frames of reference with regards to the organization and management of the ICT department in an organization, there is a relative void in the literature with regards to how these approaches can be applied in practice, and implementation is perceived as a problem and as an obstacle to reap the benefits of the application of the approaches.

There is a clear need to use proven business process reengineering techniques and tools for the (re)organization of IT management processes and to reorganize these processes, however, there are very few publications which report and elaborate on this topic. Some publications address these issues and incorporate a (often very limited) subset of BPR elements, however, there are no generally accepted methodologies and a lack of clarity about the tools that have to be used. The emphasis is most often placed on static process mapping, leaving process dynamics and stochastic behavior out of consideration.

Animated simulation is becoming increasingly popular as a tool in business process reengineering, however there is still little awareness of its benefits, and there are few (if any) generally accepted conceptual frameworks. The used conceptual frameworks are proprietary and largely different from each other, and there is a lack of general or domain-specific simulation object libraries for BPR. Very few publications were identified which report on using simulation in ICT management, however, they focus mostly on specific technical aspects of a process rather than on the organizational ones. There is also a lack of clarity about the steps that have to be followed in order to build a simulation model of ICT management processes, i.e., the approach that can be used in order to build such a model in an effective and efficient manner.

Based on the above, as well as on the personal view and experience of the author, it can be concluded that more research is necessary with regards to the use of animated simulation as a tool for the reengineering of ICT management processes. This research must focus on the following four aspects:

- Establishing a conceptual framework for the use of animated simulation for modeling ICT management processes, which takes into account both human and technical aspects of the processes, as well as the flow of information, coordination and the interaction with other processes.

- Developing a library of simulation objects, and validate it by proving that it can be used for simulating organizational aspects of ICT management processes.
- Developing an approach for building simulation models of ICT management, which describes the steps that have to be taken in order to obtain the necessary information and build, verify and validate the simulation model in an effective and efficient way.
- Exploring the benefits of animated simulation as a tool for BPR in ICT management.

These issues are in the focus of the current research on simulating ICT management processes, and are addressed in the rest of this research.

Chapter 3

Identifying ICT Management Process Characteristics: An Explorative Case

3.1 Introduction

As indicated in chapters 1 and 2, there is currently little experience with the development and use of simulation models of ICT management processes, and the few cases of ICT management simulation reported in the literature focus on specific technical aspects, rather than providing a generic basis for representing the processes and their constituent components in a simulation model. As a result of this, at the onset of this research there was a lack of clarity about two aspects of the development of such models: which characteristics of ICT management processes should be represented in a simulation model and what specific capabilities and functionality the simulation model should offer.

In order to get more information about and gain insight into these aspects, an explorative case was carried out in a mail and logistics company in The Netherlands. The explorative case and its findings are described in this chapter.

Having in mind the two aspects mentioned above, the following two objectives of the explorative case were defined:

- Identify characteristics of ICT management processes relevant to the building of simulation models of such processes.
- Define requirements about the specific capabilities and functionality that should be offered by simulation models of ICT management processes.

In order to attain the objectives of the explorative case the *case study* and *action research* approaches were used.

The *case study* approach was used to gather information about the department where the explorative case was carried out and the ICT management processes implemented there. This was accomplished by reviewing the available documentation and historical data about the department and the implemented processes, conducting interviews with people involved in the processes, as well as by direct observation of certain parts of the processes. In this way an initial description of the processes, their environment and their basic components was achieved. This included the departments involved in the processes and their role, the input to the processes and their output, as well as the communication and coordination among the different processes.

The *action research* approach was used to get more detailed information about the above mentioned aspects by direct involvement in several processes (described in the next paragraph). This allowed for gathering detailed information about the tasks carried out as part of the processes, their distribution over the people involved in the processes, the input to the tasks and the output they produce, the exchanged information within the processes, the used equipment, as well as the mechanisms used to coordinate the processes. Data were also gathered about the different events that were processed as part of the processes, the frequency of their occurrence and the duration of the different tasks.

This chapter is structured as follows. In section 3.2 a description of the explorative case is provided. In section 3.3 the findings of the explorative case are presented. Finally, in section 3.4 a summary of the explorative case and it findings is provided.

3.2 Description of the Explorative Case

In this paragraph a description of the explorative case is provided. Information about the environment of the explorative case is provided in sub-section 3.2.1. A description of the processes which were in the focus of the case is given in sub- section 3.2.2. In sub- section 3.2.3 the communication and coordination of the department where the case was carried out is described. The used equipment is described in sub- section 3.2.4. In sub-section 3.2.5 a detailed description of the workplaces in the department is provided.

3.2.1 The Environment of the Explorative Case

The explorative case was carried out at the Production department of a mail and logistics company in The Netherlands. This department was responsible for the operation of the software and technical infrastructure according to the service levels defined in the Service Level Agreements (SLA’s). Proactive management and monitoring of critical applications and components of the ICT infrastructure on a continuous basis, as well as solving incidents and problems related to them were carried out there. The department consisted of the following three departments (fig. 3.1):

- *Database and Application Management* – this department was responsible for the operation and maintenance of the production-critical applications and databases of the company. It took care of software functionality and interoperability, maintenance of data integrity, diagnosing and resolution of hardware and software errors, maintenance and upgrade of storage capacity. It also provided second-line support for database- and application-related incidents and problems and advised clients in the company with regards to database- and application-related issues.
- *Infrastructure and Network Management* – this department was responsible for the operation and maintenance of the technical infrastructure and networks of the company. It installed and maintained hardware equipment, carried out network upgrades and patches,

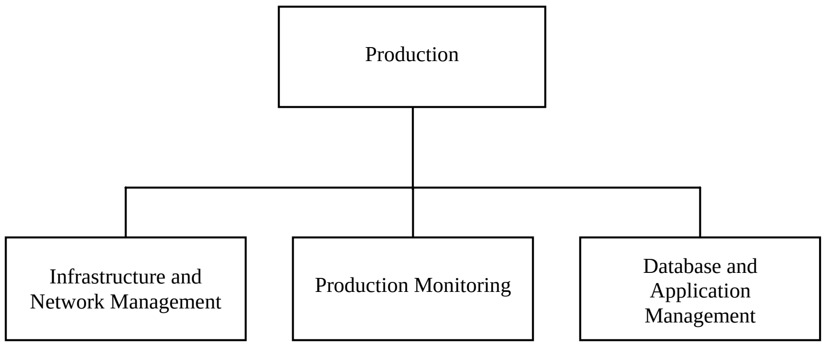

Figure 3.1: The Structure of the Production Department

took care of the interoperability of implemented network equipment, authorized and supported network users and diagnosed and resolved network connectivity and capacity problems. It also provided second-line support for network- and infrastructure-related incidents and problems and advised clients in the company regarding network- and infrastructure-related issues.

- *Production Monitoring* – this department was responsible for the monitoring of the technical infrastructure and the production-critical applications and for initiating, carrying out and coordinating corrective actions so as to minimize production disturbances and to ensure the achievement of the service levels defined in the SLA's. It configured, operated and maintained the tools necessary for the monitoring process, resolved minor infrastructure and application incidents, and initiated and coordinated the resolution process for major ones. It also coordinated and controlled the quality of incident resolution and escalated incidents for which a structural or an urgent resolution was necessary. A number of data-backup and operation tasks were carried out at this department as well.

3.2.2 Focus of the Explorative Case

The explorative case was carried out at the Production Monitoring (PM) department described above. This department was involved in the *Incident Management*, *Flashnet Administration*, *HP ITO Administration* and *Operation* processes. These processes, and more specifically the parts of the processes that were carried out at the department, were in the focus of the case. A short description of the processes and the role of the PM department in them is given below.

Incident Management

The goal of this process was to ensure the timely handling and resolution of incidents related to the functioning and use of the different components of the ICT infrastructure of the company in order to minimize their impact on the ICT services production. Several IT departments within the company were involved in this process, among which the Infrastructure and Network Management, Production Monitoring and Database and Application Management. The role of the PM department in the process was to handle incidents originating from the technical infrastructure and applications and to resolve them (first-line support) if possible, or to send them to the appropriate department(s) for further resolution otherwise. In the latter case, the PM department also took care of controlling the quality of incident resolution and eventually closing the incident.

The tasks carried out at the department as part of this process were divided into two parts: *Monitoring* and *Service Control.* The function of *Monitoring* was to monitor the technical infrastructure and applications on a continuous basis, identify (potential) production disturbances and resolve them, if possible, or to send them to the appropriate department for further resolution otherwise. The function of Service Control was to coordinate the resolution of incidents created at the PM department and ensure that the quality of their resolution meets the predefined requirements.

Flashnet Administration

The *Flashnet Administration* process consisted of first and second line support of Flashnet, a decentralized tool used for backing up data from the database servers of the company. The Infrastructure and Network Management, Production Monitoring and Database and Application Management departments were involved in this process. The role of the PM department in the process was to provide first- and second-line support for handling and resolution of Flashnet incidents. This included carrying out controls of the performed backups, rescheduling and running backups, restoring corrupt files and repairing backup configuration. Incidents, which involved network connectivity problems, replacement of hardware or changes in the software code were sent to other departments for further resolution. The progress and quality of the resolution were controlled by the PM department.

HP ITO Administration

The *HP ITO administration* process covered the support and maintenance of the Hewlett-Packard IT Operations (HP ITO) tool – a network management tool widely used within the IT departments of the company. Two departments were involved in the process - Network Management and Production Monitoring. The role of the PM department was to provide functional support for the tool and second-line support for incidents related to it. This included the maintenance of the IP map, SNMP (*S*imple *N*etwork *M*anagement *P*rotocol) event configuration, installation of agents on servers, creation and distribution of templates and maintenance of the work instructions for the tool. The PM department provided also advice regarding the use of the tool to other IT departments within the company.

Operation

The *Operation* process covered the operation and maintenance of the different components of the ICT infrastructure of the company. The Infrastructure and Network Management, Production Monitoring and Database and Application Management departments were involved in this process. Tasks related to media handling and the performing of backups were carried out at the PM department as part of the process. This included handling and administration of backup tapes and floppies and making backups. Resetting of PC's and servers and starting and stopping of batch jobs were carried out at the department as well.

More detailed information about these processes, the communication taking place as part of them, the used equipment and the tasks and activities carried out at the PM department is provided in the next sub-paragraphs.

3.2.3 Communication and Coordination of the PM Department

The PM department served as a central point for gathering information from the technical infrastructure and applications. Based on this information, it took actions to prevent disturbances in the ICT services production and/or minimize their impact. It was also

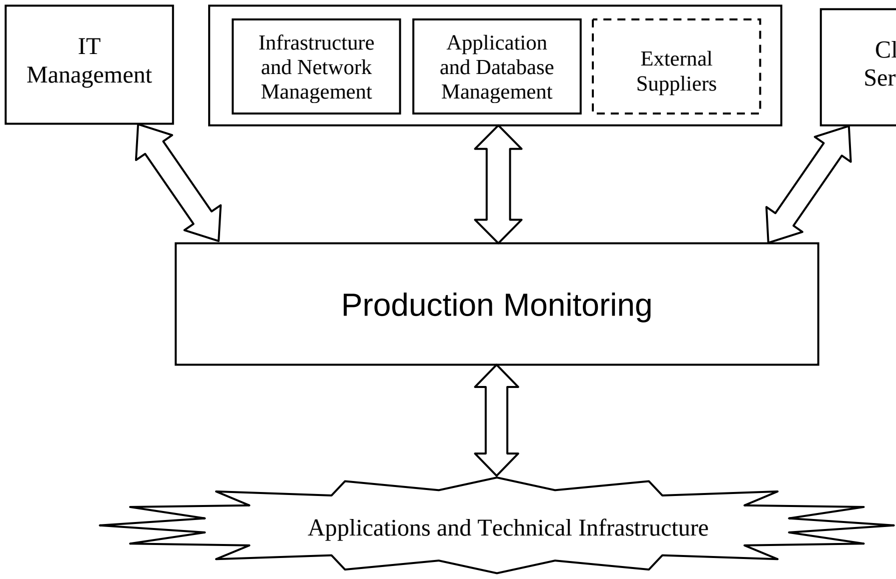

Figure 3.2: The communication of the PM department

responsible for making (relevant) parts of the gathered information available to other departments within IT Operation for the purposes of incident and/or problem resolution, end-user information or reporting.

Therefore, next to the intensive information exchange with the technical infrastructure and applications, three other “streams” in the communication between the PM department and the other IT departments within the company were identified. Firstly, communication was taking place between the PM department and the parties responsible for second- and third-line support in the process of incident resolution. This included the Database and Application Management and Infrastructure and Network Management departments, as well as a number of external suppliers. Secondly, major disturbances in the technical infrastructure and applications and their expected impact on the service levels were communicated to the Client Services department which took care of their further communication to the end-users. Thirdly, incident and performance data were communicated to the IT management of the company. The communication of the PM department is depicted on fig. 3.2.

Two team leaders coordinated the work in the department. Their tasks included the allocation of the resources of the department (human, material and financial), prioritization of the tasks of the staff, as well as ensuring that the performance of the department met the predefined targets. An important part of the work of the team leaders was the escalation of incidents.

They were responsible for escalating the incident to their peers and higher in the hierarchy, and for coordinating the process of its resolution. The team leaders also attended different meetings on operational and/or organizational issues.

The communication and coordination within the department, as well as with the other departments were carried out by means of exchanging **pieces of information** or **information objects** in the form of messages, trouble tickets, reports, etc. The objects received by the department were used as triggers for certain actions. As a result of these actions other objects were produced and sent to the appropriate department. The received and produced objects, as well as the types of objects exchanged with the other departments and the information they carried were relatively well defined, and a standard set of actions was taken upon receiving a certain type of object. An important characteristic of an information object was its priority, which reflected the extent to which the information carried by the object was critical to the operation of the department and indicated the speed with which the object had to be processed.

3.2.4 Equipment

Different kinds of **equipment** were used in the PM department in order to enable and facilitate the tasks carried out as part of the processes described above. The characteristics of the equipment had a strong influence on the effectiveness and efficiency of the work carried out in the department.

The equipment included hardware (personal computers, servers and printers) and several software tools. The most important of the software tools were the Hewlett-Packard IT Operations (HP ITO), the WiX database and the PM agenda. These tools are described below.

The *HP ITO* was the basic tool used in the department. It provided capabilities as message browsing, SNMP event configuration, network management and configuration management. The tool was used by the people working in the department to continuously monitor incoming messages, diagnose incidents and perform remote actions on the network and technical infrastructure in order to resolve them. It was also coupled with the trouble-ticket tool used in the IT departments of the company, which facilitated to a great extent the incident management process in the department.

The *WiX* database was a work instruction database developed at the department. It contained work instructions that had to be carried out in order to handle a certain kind of event. At the time of carrying out the explorative case the database contained instructions for about 70% of the events, monitored in the department. The use of the WiX tool facilitated the handling of events and significantly reduced the time and the human errors in the process of their resolution.

The *PM agenda* was a groupware tool, which contained a list of issues, which had to be taken into account in the daily work of the department. This included such items as planned production disturbances, scheduled backups, batch jobs start/stop, PC resetting and planned server maintenance. It was also used to announce requested backups and media handling activities and to provide information about the date and time they had to be carried out and delivered to the requesting department. Available on all workplaces in the department, the PM agenda improved significantly the efficiency and the coordination of the work at the PM department.

Every workplace within the PM department was equipped with a Pentium-based PC, an X-terminal and a telephone. The PCs were connected to the Novell-based network of the company. They were used for running e-mail and other information-exchange software, the PM Agenda and some small databases, and for producing reports. The X-terminals were connected to the UNIX-based network of the company. They were used for running HP ITO, the WiX work instruction database and some network management utilities.

The following sections provide more detailed information about the workplaces at the PM department and about the way in which the tools and the equipment were used to carry out the tasks at these workplaces.

3.2.5 Tasks and Workplaces of the PM Department

The work at the PM department was divided into **tasks** carried out by the people working there. A task was oriented at processing certain input objects and producing a predefined result depending on the type and characteristics of the input objects. It was further divided into one or more logically related **activities** which represented atomic units of work within the task. The order in which tasks and their constituent activities were carried out was determined by the priority of the input objects. The exact activities that were carried out as part of a task and their sequence depended on the characteristics of the objects. A task could be interrupted and its execution postponed in case an object with a higher priority arrived and quick action needed to be taken.

The **workplace** formed the basic building block for the structure of the department and the processes carried out there. It comprised a set of closely related tasks and included the equipment necessary to carry them out. One or more **workers** worked at each workplace and workers working at the same workplace carried out identical tasks. The workers of the department changed their workplaces on an ad-hoc or regular basis.

Based on the description of the PM department presented in the previous section and the identified generic process elements, the following workplaces were identified in the department: Monitoring, Service Control, Flashnet Administrator, Operator, ITO Administrator, Team Leader. In the following paragraphs a detailed description of these workplaces and the tasks and activities carried out there is provided.

Monitoring

Monitoring of technical infrastructure and applications (incident detection and handling) was the basic function of PM. It was carried out 24 hours a day, 7 days a week. The basic working process consisted of reviewing the messages from the technical infrastructure and the business applications coming in the HP ITO browser. Upon arrival of a message, an initial investigation was carried out to determine the disturbance that caused the event ‘announced’ by the message. After that a check was performed in order to determine whether there was a standard sequence of actions (the so-called “standard solution”) that had to be followed in order to handle the event. This comprised searching the PM Agenda and the WiX database for a standard solution related to the event. A search in the PM Agenda was carried out in order to determine whether the event is a result of scheduled maintenance or a known problem, and whether a predefined set of actions existed that had to be carried out in order to handle it. If the event was not in the PM Agenda, a search in the WiX database was performed to check for work instructions that needed to be carried out to handle the event. If a standard solution existed, the work instructions it consisted of were carried out in order to solve the disturbance that caused the event. If a standard solution did not exist, or the disturbance could not be solved by applying the existing standard solution, a trouble ticket was created and sent to the appropriate department for further resolution. Finally, the message was sent to the message archive (the so-called ‘acknowledging’ of the message). The logical flow of activities for this process is described in fig. 3.3. It should be noted that in practice this logical flow is carried out in an iterative manner. However, for the sake of clarity, this is not explicitly included in the figure. The tasks carried out at the Monitoring workplace and their constituent activities were defined as follows:

- *Monitor* – this tasks consisted of the following activities:
  - *Check for new messages* – consisted of continuously checking the messages in the HP ITO message browser. If there were new messages, the ones with the highest priority were handled first.
  - *Lock message* – consisted of “taking possession” of the currently handled message. The message was still visible in the browser, but other people engaged in the monitoring process could not make changes to it. In this way the workload could be effectively distributed and duplicate handling of the same message(s) was avoided.
- *Investigate message* – this task consisted of activities carried out in order to establish the cause of the message. These activities were:
  - *Initial investigation* – consisted of determining the event that generated the message and its impact. This was done by reviewing the additional information accompanying the message. However, in some cases additional actions like logging remotely on servers or using tools for monitoring network equipment and workload were necessary.
  - *Check PM agenda* – after the event that caused a message was determined, a check in the PM agenda was performed to see whether the event was a result of scheduled maintenance activities or known problems.
  - *Check WiX* – if an event was not present in the PM agenda, a check in WiX was performed to see whether there was a standard sequence of actions that had to be carried out in order to handle the event. If that was not the case, a TT was created and sent to the departments providing second- and third-line support for further investigation and resolution.
- *Process message* – this task consisted of activities necessary to handle the message according to its underlying cause and the severity of its impact. These activities were:
  - *Follow PM agenda instructions* – if an event was present in the PM agenda, often special actions needed to be carried out for its further handling. These actions were described in the PM agenda instructions for the specific message.
  - *Follow WiX instructions* – consisted of carrying out the sequence of actions described in WiX for the specific event. This involved a detailed investigation and diagnosis of the event, performing network management actions from within HP ITO, resetting

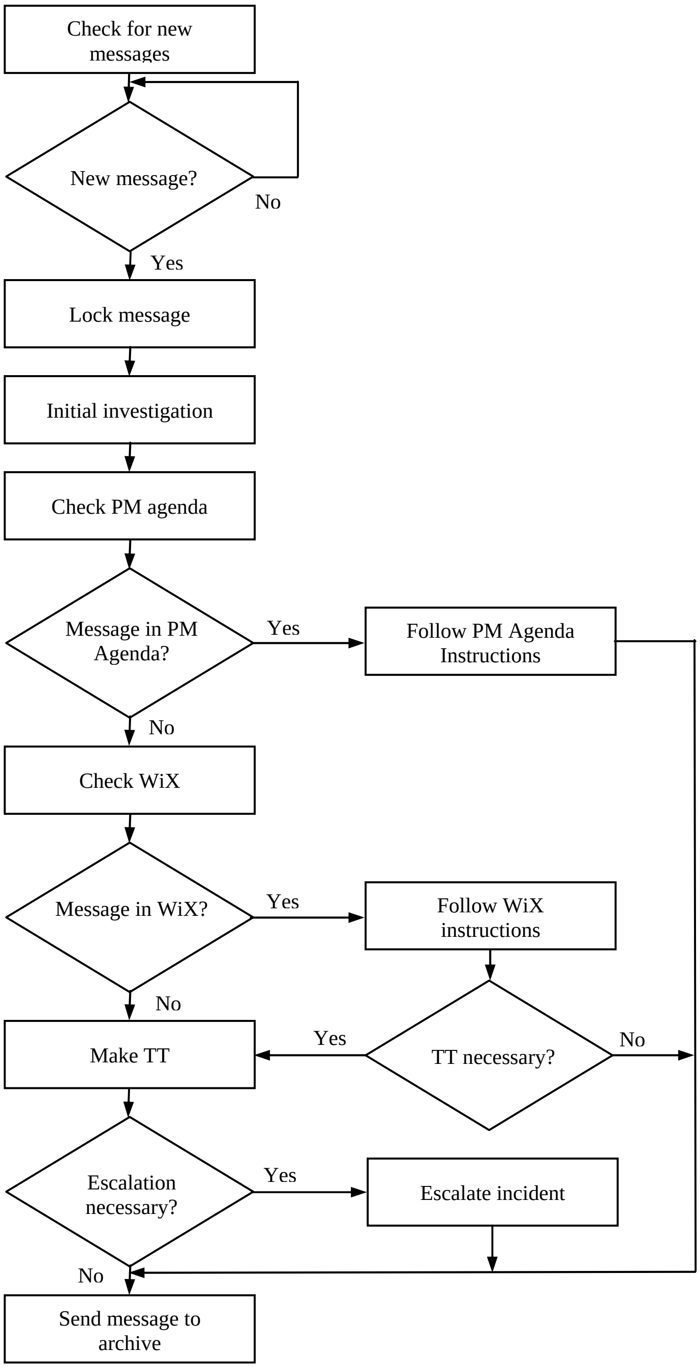

Figure 3.3: Flowchart of the Monitoring activities

network equipment or restoring corrupt files and data. In some cases the creation of a TT was necessary.

- *Make TT* – consisted of creating an incident report for a specific event by filling in a trouble ticket and sending it to the departments providing second- and third-line support.

The TT contained the message generated by the event, the additional data sent with the message, as well as the results of the investigation carried out at the PM department

- *Escalate incident* – consisted of escalating incidents with (potentially) big impact on the ICT services production. The escalation comprised informing the team leaders of the department about the incident, establishing contact with the departments responsible for its resolution, and, if necessary, informing the Client Service department about the incident and its possible consequences on the service levels.
- *Send message to archive* – after a message had been handled, i.e., the event had been resolved at the PM department or a TT had been created and sent to the appropriate department, the message was sent to archive and was no longer visible in the HP ITO message browser.

The messages processed at the Monitoring workplace were generated by the applications and technical infrastructure of the company on a 7x24 hour basis. They were divided into four basic categories with regards to their severity:

- *Information* – indicated the occurrence of a normal event in the operation of the applications and technical infrastructure. No special action needed to be taken to handle the message.
- *Warning* – indicated the occurrence of an event, which could possibly lead to (or is a result of) malfunction in the operation of the applications and technical infrastructure. If the event occurred repeatedly, action was taken to identify and resolve the cause.
- *Error* – indicated the occurrence of a malfunction in the operation of the applications and technical infrastructure. The impact of the malfunction was limited and did not require immediate action for its resolution, however the malfunction had to be resolved in order to restore normal operation.
- *Critical* – indicated the occurrence of a serious malfunction in the operation of the applications and technical infrastructure. The impact of the malfunction was big and could lead to service unavailability or loss of data. Immediate action was required to restore normal operation.

There were certain patterns with regards to the frequency with which the messages arrived at the PM department. For example, the frequency of message generation during the office hours on weekdays was higher than the frequency in the evening hours or in the weekends. On the other hand, the percentage of messages of the type "*error*" and "*critical*" was higher during the evening hours and the weekends. There were two peak periods during the office hours – from 10.00 a.m. till 12.00 a.m. and from 13.30 p.m. till 15.30 p.m. – during which the frequency of message arrival was much higher than the rest of the day. The percentage of the messages resulting in the creation of a trouble ticket varied depending on the message type. For messages of the type "*critical*" this was 90%, for the type "*error*" – 40%, and for the type "*warning*" – 5%. For messages of the type "*information*" no trouble ticket was created. Approximately 50% of all created trouble tickets were sent to the *Infrastructure and Network Management* department, 40% to the *Application and Database Management* department, and 10% to external suppliers. The frequencies of message arrival according to the time of arrival and the percentage of the different types of messages are given in table 3.1. The data in the table represent average values based on data from the HP ITO browser over a period of three months.

Period	*Frequency of arrival (messages per hour)*			*% Information*	*% Warning*	*% Error*	*% Critical*
	Min.	*Avg.*	*Max.*				
Workdays from 8.00 a.m. till 6.00 p.m. (excl. peek hours)	10	25	90	10	30	50	10
Workdays peek hours (10.00 a.m. till 12.00 p.m. and 1.30 p.m. till 3.30 p.m.)	30	60	100	10	40	40	10
Workdays from 6.00 p.m. till 8.00 a.m. and weekends	5	10	80	5	10	60	25

Table 3.1: Frequencies of arrival and type of messages according to the period of arrival.

The tasks and activities carried out at the *Monitoring* workplace in order to process a message and their duration varied according to the type of the message. The duration of these tasks and activities in minutes is given in table 3.2. The data in the table represent average values based on data obtained from interviews with people involved in the process, as well as the personal observations of the author over a period of three months.

Activity	*Min.*	*Avg.*	*Max.*
Check for new messages	0.5	0.5	1
Lock message	0.5	0.5	1
Initial investigation	1	3	6
Check PM agenda	2	4	5
Follow PM agenda instructions	2	5	10
Check WiX	3	4	7
Follow WiX instructions	4	8	20
Make TT	2	3	5
Escalate incident	5	7	30
Send message to archive	0.5	0.5	0.5

Table 3.2: Duration of the activities carried out at the Monitoring workplace

Service Control

The main goal of Service Control was to ensure that the resolution of incidents created at the PM department was done within the predefined time and quality constraints. It consisted of checking on a regular basis the status of the trouble tickets created at the department. If a trouble ticket was resolved, the quality of the incident resolution was checked. If the resolution met the predefined quality requirements the incident was closed. Otherwise it was

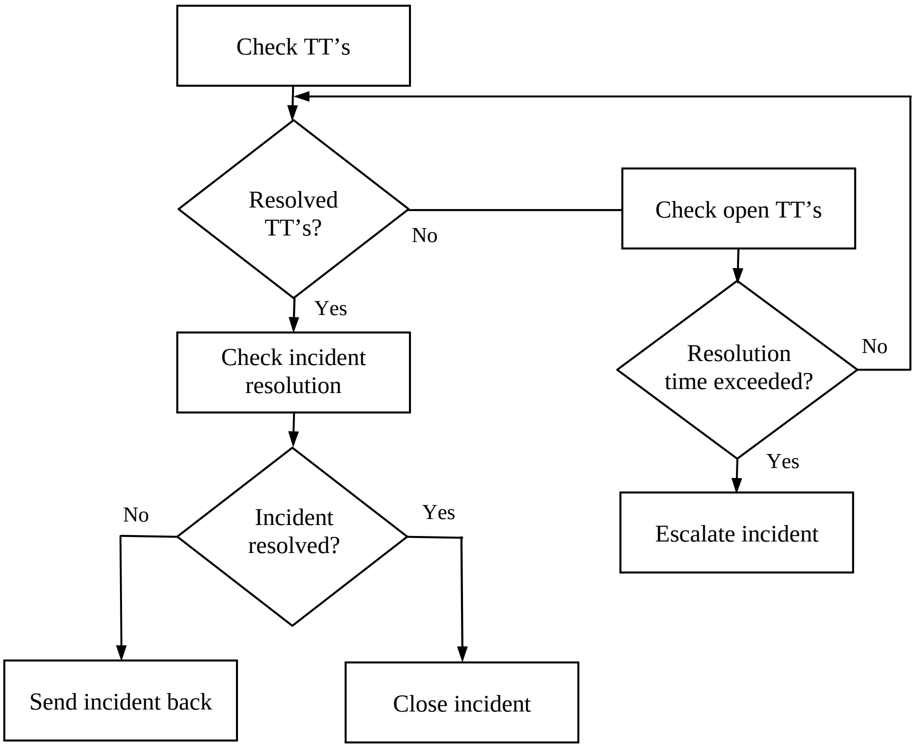

Figure 3.4: Flowchart of the Service Control process

sent back for further resolution. The status of the incidents that were still in the process of resolution was also checked. If the resolution of an incident took longer than the predefined resolution time, the priority of the incident was increased, or the incident was escalated. This sequence of actions is depicted on fig. 3.4. It should be noted that in practice this sequence is carried out in an iterative manner. However, for the sake of clarity, this is not explicitly included in the figure.

The tasks carried out at the Service Control workplace were defined as follows:

- *Check trouble tickets* – this task consisted of checking on a regular basis the status of the TT's created at the department. The following two activities were part of the task:
  - *Check resolved TT's* – consisted of reviewing the status of trouble tickets created at the PM department. Resolved trouble tickets were selected for further handling (solution check and closing).
  - *Check open TT's* – consisted of checking the status of trouble tickets, which were still in the process of resolution by departments providing second- and third-line support or external suppliers.
- *Check incident resolution* – consisted of reviewing the actions taken to resolve the incident and their results. The quality of the resolution was determined by checking parameters of the applications and technical infrastructure, and/or calling the users affected by the incident. A check was also carried out in order to determine whether the time constraints for resolving the incident were met. The result of this task determined which task(s) had to be carried out next.
- *Close incident* – if the incident resolution met the predefined quality parameters the incident was closed and the trouble ticket was sent to archive.

- *Send incident back* – if the quality of the incident resolution did not meet the predefined quality requirements, the incident was sent back to the appropriate department for further resolution.
- *Escalate incident* - if the resolution time limits defined for the specific type of incident were exceeded the incident was escalated by increasing its priority and/or informing the team leaders of the department.

The task *Check Trouble Tickets* was carried on a regular basis every 10 minutes. The frequency of carrying out the rest of the tasks of this workplace depended on the frequency of incident creation at the *Monitoring* workplace and the time for their resolution.

The duration in minutes of the tasks and activities carried out at the *Service Control* workplace is given in table 3.3. The data in the table represent average values based on data obtained from interviews with people involved in the process, as well as the personal observations of the author over a period of three months.

Activity	*Min.*	*Avg.*	*Max.*
Check trouble tickets	1	1	2
Check incident resolution	3	8	20
Send incident back	2	2	4
Check open TT's	2	2	5
Escalate incident	5	7	30
Close incident	1	2	5

Table 3.3: Duration of the tasks and activities of *Service Control*

Flashnet Administration

Flashnet was a decentralized backup system for UNIX and NetWare servers used at the company. Both the monitoring and part of the problem resolution for Flashnet were carried out at the PM department. The working sequence was as follows. First, the report on 'Flashnet' events, automatically generated every day in the department was checked. If an incident was identified, investigation of the incident details was carried out and a diagnosis was made of the underlying causes. If it was possible to solve the incident by software means, the resolution was carried out at the PM department. Otherwise, a trouble ticket was created and sent to the appropriate department. The control of the resolution process was also carried out at this workplace. This working sequence is depicted on fig. 3.5. It should be noted that in practice this sequence is carried out in an iterative manner. However, for the sake of clarity, this is not explicitly included in the figure.

The tasks carried out at the Flashnet workplace were defined as follows:

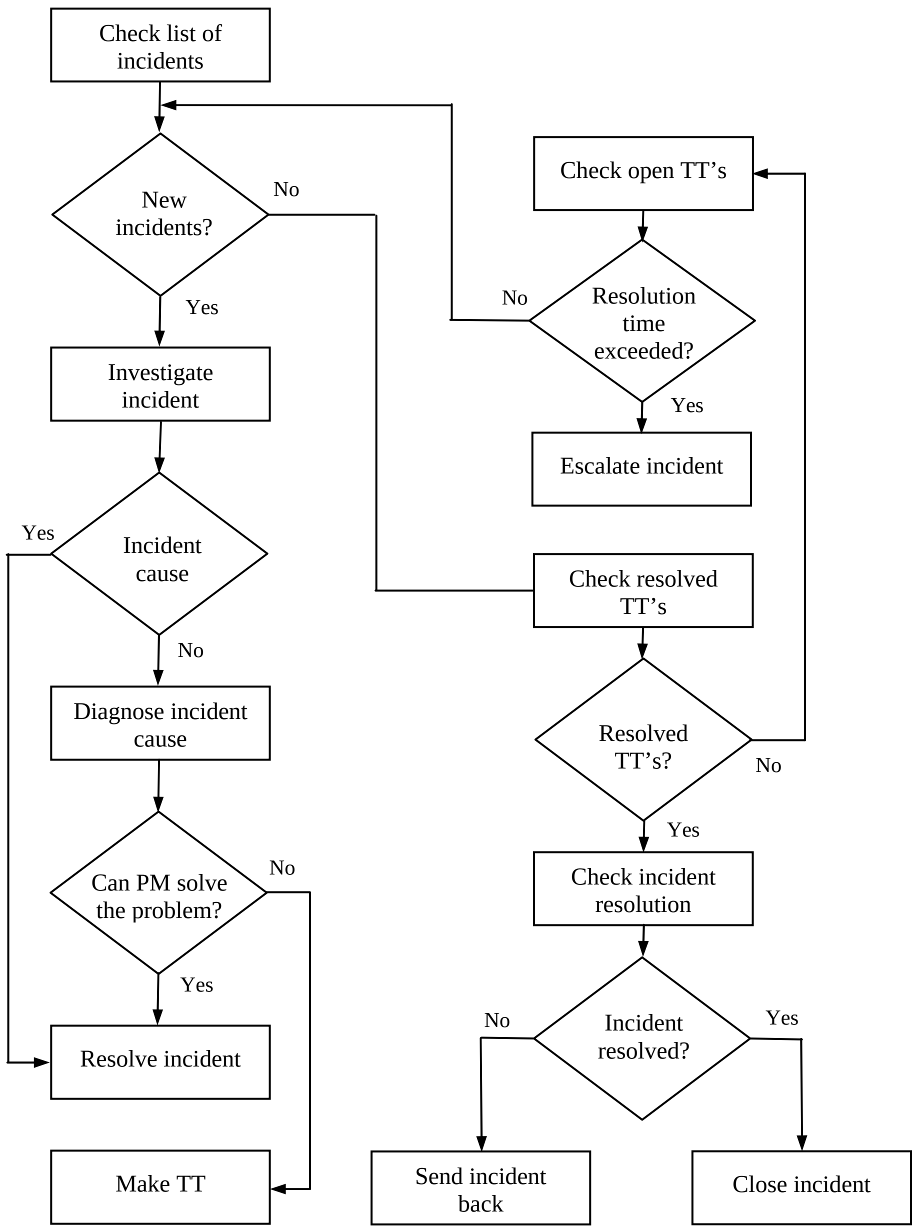

Figure 3.5: The working sequence of Flashnet administration

- *Check Flashnet incidents* – consisted of checking the list of Flashnet incidents automatically generated at the department. The incidents were identified and their severity and impact were determined.
- *Diagnose incident* – consisted of establishing the cause of an incident. This encompassed the following two activities:
  - *Investigate incident* – consisted of collecting detailed information about an incident. Included checking the HP ITO browser for specific messages related to the

investigated incident, logging on remotely to faulty machines, checking system files and performing tests.

  - *Diagnose incident cause* – on the basis of the information obtained in the previous step, crosschecks were performed and a diagnosis was made about the causes of the incident. This diagnosis determined the further handling of the incident.

- *Handle incident* – based on the incident diagnosis carried out in the previous task, one of the following activities was carried out for the further handling of the incident:

  - *Resolve incident* – if the resolution of the incident could be done by software means, it was carried out at the PM department. This included rescheduling backups, restoring files and data and repairing system configurations.

  - *Make TT* – if an incident was caused by a failure in a network component or storage media, a trouble ticket was created and sent to the appropriate department for resolution.

- *Check trouble tickets* -– this task consisted of checking on a regular basis the status of the TT's created at the workplace. The following two activities were part of the task

  - *Check resolved TT's* - consisted of reviewing the status of trouble tickets created at the Flashnet Administration workplace. Resolved trouble tickets were selected for further handling.

  - *Check open TT's* - consisted of checking the status of trouble tickets, which were still in the process of resolution by departments providing second- and third-line support or external suppliers.

- *Check incident resolution* - consisted of reviewing the actions taken to resolve the incident and their result. The quality of the resolution was determined by checking parameters of the servers and data involved in the backups.

- *Handle incident* – depending on the result of the previous task, one of the following activities was carried out as part of this task:

  - *Send incident back* - if the quality of the incident resolution did not meet the predefined quality requirements, the incident was sent back to the appropriate department for further resolution.

  - *Escalate incident* - if the resolution time limits defined for the specific type of incident were exceeded the incident was escalated by increasing its priority and/or informing the team leaders of the department.

  - *Close incident* - if the incident resolution met the predefined quality parameters the incident was closed and the trouble ticket was sent to archive.

The frequency of arrival of Flashnet incidents at the PM department depended on the day of the week – every workday incremental backups of user and application data were carried out between 10.00 p.m. and 5.00 a.m. In the weekend full backups of these were carried out, scheduled throughout the day. The frequency of arrival of Flashnet incidents is given in table 3.4. The data in the table represent average values based on Flashnet data over a period of three months.

Period	*Frequency of arrival*			*% Warning*	*% Error*	*% Critical*
	Min.	*Avg.*	*Max.*			
Workdays from 10.00 p.m. till 5.00 a.m.	15	35	60	30	60	10
Weekends	20	50	70	25	60	15

Table 3.4: Frequency of arrival of Flashnet incidents

The tasks and activities carried out at the *Flashnet Administration* workplace depended on the frequency and type of Flashnet incidents. The approximate duration of these tasks and activities in minutes is given in table 3.5. The data in the table represent average values based on data obtained from interviews with people involved in the process, as well as the personal observations of the author over a period of three months.

Activity	*Min.*	*Avg.*	*Max.*
Check Flashnet incidents	5	10	20
Investigate incident	3	5	10
Diagnose incident cause	5	10	30
Resolve incident	12	20	45
Make TT	5	10	15
Check resolved TT’s	1	1	2
Check open TT’s	2	2	5
Check incident resolution	5	10	25
Send incident back	2	2	4
Escalate incident	5	7	30
Close incident	1	2	5

Table 3.5: Duration of the tasks and activities of *Flashnet Administration*

Operator

A number of operation tasks were performed at the Operator workplace in the PM department. These tasks were not directly related to the process of monitoring and service control, and were carried out at the department for historical reasons. Most of the tasks were related to media handling and the carrying out of backups. However, tasks like resetting PC’s and servers and manipulation of batch jobs were also carried out here. The tasks of the Operator were defined as follows:

- *Media handling* – consisted of the intake, administration and distribution of backup tapes. Tapes arrived regularly at the department and had to be sorted, labeled and prepared for carrying out a backup. After the backup was carried out the tapes were distributed to the appropriate departments for further storage.

- *Carrying out backups* – consisted of placing the tapes in the backup devices and carrying out the backups. The backup process was monitored for errors and failures.
- *Resetting PC's and servers* – consisted of rebooting certain PC's and servers at predefined times. Shutdown procedures were carried out and action was taken in case of reboot failures.
- *Manipulation of batch jobs* - consisted of the scheduling, starting and stopping of batch jobs on certain servers. The execution of the jobs was monitored for errors and failures.

The tasks at the *Operator* workplace were carried out on a regular basis daily or weekly. The duration of these tasks in minutes and their frequency are given in table 3.6.

Task	*Duration*			*Frequency*	
	Min.	*Avg.*	*Max.*	*Times*	*Per*
Media handling	90	150	180	3	week
Carrying out backups	60	90	120	2	day
Resetting PC's and servers	30	45	60	1	day
Manipulation of batch jobs	15	30	60	6	day

Table 3.6: Duration and frequency of the *Operator* tasks

HP ITO Administrator

The administration of the HP IT Operations tool was carried out at the PM department by the ITO administrator. As mentioned above, this was one of the most important and commonly used network management tools in the IT department of The company. The ITO administrator took care of the operational use and maintenance of the tool, provided second-line support for incidents related to the tool, wrote and maintained work instructions, provided advice to projects for developing new solutions, and participated in the implementation of these solutions. The tasks, carried out by the HP ITO administrator were defined as follows:

- *Operational use of HP ITO* – included the installation of agents on servers, the creation and distribution of templates, SNMP event configuration, and the creation and keeping of operator profiles, node groups and application groups.
- *Maintenance of HP ITO* – included the installation of patches and upgrades of the tool, as well as the maintenance of the IP map, the operator maps and the network map.
- *Support for incidents related to HP ITO* – consisted of the resolution of incidents related to the functionality of HP IPO or the underlying infrastructure.

- *Writing and maintenance of work instructions* – consisted of defining and maintaining the sequences of actions (work instructions) for handling a certain event, and the way in which they had to be carried out. These work instructions were then entered in the WiX database, and were available for use to the people working in the department.
- *Advise on HP ITO issues* – consisted of providing advice to departments in the company and projects for developing new applications with regards to the functionality and capabilities of HP ITO and the steps that have to be taken in order to make an application suitable for monitoring and management with the tool.
- *Take new solutions into production* – consisted of the creation of monitoring templates and configuration of SNMP events for newly implemented applications and the definition of work instructions for handling these events.

The tasks at the *HP ITO Administrator* workplace were carried out on a regular basis daily, weekly or monthly. The duration of these tasks in minutes and their frequency are given in table 3.7.

Task	*Duration*			*Frequency*	
	Min.	*Avg.*	*Max.*	*Times*	*Per*
Operational use of HP ITO	30	60	150	5	day
Maintenance of HP ITO	45	75	120	1	week
Support for incidents related to HP ITO	60	120	240	5	week
Writing and maintenance of work instructions	45	60	90	1	day
Advise on HP ITO issues	60	120	360	1	week
Take new solutions into production	360	860	1720	2	month

Table 3.7: Duration and frequency of the *HP ITO Administrator* tasks

Team Leader

The Team Leader was responsible for the management of the work at the PM department. He coordinated the activities carried out at the department, allocated the human, financial and technical resources of the department, and ensured that the performance of the department met the agreed levels. The Team Leader was also responsible for the escalation of incidents and problems, for providing advice to clients within the company with regards to production monitoring issues, and for attending meetings where operational and/or organizational issues were discussed. The tasks of the Team Leader were defined as follows:

- *Coordinate department activities* – consisted of distributing and coordinating the tasks of the people working in the department, taking care of the duty roster, prioritizing the work carried out at the department and informing the staff about requirements and preconditions imposed on the department by the management.
- *Allocate resources* – consisted of distributing the available people and equipment for carrying out the routine tasks at the department and working on projects so that to ensure the effective and efficient use of the budget of the department.

- *Monitor performance* – consisted of receiving and reviewing on a regular basis reports about key performance indicators regarding the work of the department, comparing these indicators with the levels defined in the SLA's and the requirements and preconditions imposed by the management, and taking corrective action if necessary.
- *Escalate incidents* – consisted of taking actions for initiating the resolution of urgent incidents or increasing the priority of incidents for which the resolution time had been exceeded. This included establishing and maintaining contact with the involved parties and taking active part in the coordination of the resolution process until the incident was resolved.
- *Advise on production monitoring issues* – consisted of providing expert advice to projects and departments of the company with regards to the services offered by the department, its requirements and preconditions, the carried out tasks and the working procedures in place.
- *Attend meetings* – consisted of participating in meetings and consultations about issues, which had impact on the work of the department, incidents and problems that had to be solved, projects, in which the department was involved and coordination with external suppliers.
- *Report* – consisted of providing information about the work of the PM department in the form of reports and sending them to the IT management of the company. The reports contained information about the number of incidents received at the department, the number of incidents resolved at the department and at other departments, the number of open incidents, the extent to which the time constraints for incident resolution were met, as well as the number and resolution time for incidents escalated at the department. These reports were usually produced on a weekly basis.

The tasks at the *Team Leader* workplace are carried out on a regular basis daily, weekly or monthly. An exception to this rule is the escalation of incidents and problems, which is carried out on an as-needed basis, and the frequency of its occurrence depends strongly on the frequency of incident escalations at the *Monitoring* and *Service Control* workplaces. The duration of the tasks in minutes and their frequency are given in table 3.8. The data about the escalation of incidents represent the average amount of time spent on this task per week.

Task	*Duration*			*Frequency*	
	Min.	*Avg.*	*Max.*	*Times*	*Per*
Coordinate department activities	15	30	60	6	day
Allocate resources	45	60	90	2	week
Monitor performance	30	45	60	1	day
Escalate incidents	30	60	120	1	week
Advise on production monitoring issues	45	60	150	1	week
Attend meetings	60	90	120	4	week
Report					

Table 3.8: Duration and frequency of the *Team Leader* tasks

3.3 Findings of the Explorative Case

In this paragraph the findings of the explorative case are presented. In line with the objectives of the case described in section 3.1, the findings are divided into two parts. In the first part (sub- section 3.3.1) characteristics of ICT management processes relevant to the building of simulation models are described. In the second part (sub- section 3.3.2) requirements for simulation models of ICT management processes are formulated.

3.3.1 ICT Management Process Characteristics

The ICT management process characteristics identified in the course of the explorative case can be divided into two main categories: *generic process characteristics* which can be found in most or all process implementations, and *implementation-specific process characteristics* which are highly volatile and vary with each specific process implementation. These two categories are described below.

Generic process characteristics

The generic process characteristics identified in the course of the explorative case were related to the structure of the processes and did not depend on their concrete implementation. These characteristics were included in the description of the explorative case provided in the previous paragraph and can be summarized as follows:

- The communication taking place as part of the studied ICT management processes was carried out by exchanging **pieces of information** or **information objects** in the form of messages, trouble tickets, reports, etc. The information objects received by the department were used as a trigger for taking certain action(s), and as a result of this other information objects were produced. Three typical characteristics of an information object were the *type* of the object, the *information* it carried and its *priority*. The priority reflected the extent to which the information carried by the object was critical to the process it was part of, and was used to determine the speed with which the object had to be processed.
- The work carried out as part of the processes was divided into **tasks**. A task was triggered by an information object and produced a predefined result depending on the type and characteristics of the object. It consisted of one or more logically related **activities**. The exact activities that were carried out as part of a task and their sequence depended on the characteristics of the processed object. A task could be interrupted and its execution postponed in case an information object with a higher priority arrived and had to be processed.
- Different kinds of **equipment** were used to enable the execution of tasks. This equipment included hardware and software tools. The characteristics of the equipment had a strong influence on the effectiveness and efficiency of the work carried out as part of the studied processes.
- The **workplace** formed the basis for the structure of, on the one hand, the department where the explorative case was carried out, and, on the other hand, the processes studied in the course of the case. At each workplace a set of closely related tasks were carried out and it included the equipment necessary to carry them out.

- One or more **workers** worked at each workplace. Workers working at the same workplace carried out identical tasks. The workers of the department changed their workplaces on an ad-hoc basis depending on the workload, or on a regular basis according to the rooster used at the department.

Due to the fact that these characteristics are related to the structure of the studied ICT management processes, the elements they refer to are considered to be *generic elements of the process structure* and are referred to in this way in the rest of this thesis. These elements are the *information object*, the *task* and its constituent *activities*, the *equipment* used as part of the processes, the *workplaces* and the *workers* working at these workplaces.

Implementation-specific process characteristics

The implementation-specific characteristics, as their name suggests, depended on the concrete implementation of the studied processes. These characteristics can be described as follows:

- *The implementation of the generic elements of the process structure* - included the different types of information objects and their specific characteristics, the content of the tasks and their constituent activities, the used equipment, the definition of the workplaces and the workers working at these workplaces;
- *The logic of the processes* – included the logic that determined the flow of information objects among the workplaces involved in a process and defined the rules used at the different workplaces to determine the tasks that had to be carried out in order to process the input information objects for a workplace.
- *Quantitative information about the processes* - included information about the frequency of occurrence of certain events in the processes (e.g., the arrival of messages in the HP ITO browser) and information about the duration of the different tasks and activities carried out as part of the processes.

3.3.2 Simulation Model Requirements

On the basis of the process characteristics described above, requirements were defined with regard to the capabilities and functionality of a simulation model of ICT management processes. These requirements are as follows:

- The model should capture and visualize the workplaces that are part of the processes under investigation and the people working at these workplaces.
- The model should capture the tasks carried out as part of the processes, their constituent activities, the input triggering them and the result they produce.
- The model should capture and visualize the information objects representing the flow of information among the workplaces and the changes in their status as a result of their processing.
- The model should capture and visualize the equipment used to carry out the different tasks and activities and the way in which the people use this equipment.
- The model should capture the process logic guiding the flow of information objects among the workplaces and the selection and execution of tasks at these workplaces.

3.4 Summary

In this chapter an explorative case carried out at the Production Monitoring department of a mail and logistics company was presented. The objectives of the case were to gather information about characteristics relevant to the building of simulation models of ICT management processes and define requirements with regard to the capabilities and functionality of such models. In relation to this, the results obtained in the course of the case can be summarized as follows:

- During the explorative case a number of generic characteristics of ICT management processes were identified. On the basis of these characteristics generic elements of the process structure were defined which included the *information objects* used to exchange information, the *tasks*, into which the work is divided and the *activities* they consist of, the *equipment* used to carry out these tasks, the *workplaces* at which the tasks are carried out and the *workers* working at these workplaces.
- Three implementation-specific characteristics of ICT management processes were also identified in the course of the case. These characteristics depended on the concrete implementation of the processes and included the concrete implementation of the generic elements of the process structure, the logic guiding the flow of information objects and the selection and execution of tasks at the workplaces, as well as quantitative information about the frequency of occurrence of certain events in the processes and the duration of the tasks and activities carried out as part of them.
- Based on the identified process characteristics, requirements were defined with regard to the capabilities and functionality that should be offered by simulation models of ICT management processes.

The explorative case described in this chapter and its findings served as a basis for the framework and the approach for simulating ICT management processes presented in chapters 4 and 5, and for building the simulation models described in chapters 6 and 7.

Chapter 4

A Framework for Simulating ICT Management Processes

4.1 Introduction

In chapters 1 and 2 the need for a generic conceptual framework in the field of ICT management processes simulation and the benefits of using such a framework were discussed based on the research reported in the literature. The need for developing a set of reusable modeling constructs for simulating such processes was also explained and the way in which the use of such constructs can increase the effectiveness and efficiency of building simulation models was described. In chapter 3 a number of generic elements of ICT management processes were identified based on an explorative case and requirements were defined with regard to the functionality and capabilities of simulation models of this kind of processes.

Based on this, in this chapter a conceptual framework and a set of modeling constructs for the simulation of ICT management processes are proposed. The conceptual framework consists of a set of generic concepts for the modeling of ICT management processes based on the generic process elements identified in chapter 3 and provides a description of their basic characteristics and relationships. Based on the concepts a set of modeling constructs are defined in the form of a library of object classes for simulating ICT management processes. The characteristics and functionality of the classes of the library as well as their implementation are described. The way of modeling specific aspects and situations (e.g., the interruption of a task by a task with higher priority or the interactions taking place at the workplace) is explained. In relation to this, the following two main goals of this chapter are defined:

- Propose a conceptual framework for the simulation of ICT management processes and provide a description of the basic characteristics and relationships of the elements of this framework.
- Define a library of object classes for the simulation of ICT management processes, specify their characteristics, functionality and relationships, explain the way in which specific aspects and situations are modeled and describe the implementation of the object class library including the means provided for configuring the different classes as well as their visualization.

The chapter is structured as follows. In section 4.2 a conceptual framework for simulating ICT management processes is presented, the concepts are specified and their relationships are defined. In section 4.3 a library of object classes for simulating ICT management processes is described, the characteristics, functionality and interrelationships of the object classes are specified, and the implementation of the library in the form of a simulation template is presented. Finally, in section 4.4 conclusions are made with regards to the conceptual framework and the library of object classes, issues related to their use are discussed and the next steps in the research are outlined.

4.2 A Conceptual Framework for Simulating ICT Management Processes

As explained in chapter 2, due to the little research in the area, there are currently very few generally applicable concepts in the area of ICT management simulation. Therefore, a conceptual framework for simulating ICT management processes is proposed as part of this research. Such a framework can help for bringing intellectual structure to a disjoint field (Wastell et al, 1994) or to a field where little research has been done and few generally accepted concepts are available. It should be tailored to its area of application, and forms the "architectural basis" for developing a conceptual model (Franken and de Weger, 1997; Pritsker et al, 1997) of the processes under investigation (the development of the conceptual model and its use are discussed in more detail in chapter 5). The conceptual framework and its elements are presented in the next sections.

The proposed conceptual framework for ICT management processes simulation is based on the generic process elements identified in chapter 3 and comprises the concepts *information object, task, equipment, workplace* and *IT worker*. These concepts are defined as follows:

- *Information object* – a piece of information exchanged by the people involved in the ICT management processes, used for communication and coordination of their work. An information object can have different *types*, and can represent both tangible (e,g., a report, a trouble ticket. an e-mail) and intangible (e.g., a phone call, a verbal communication) pieces of information. Two categories of information objects can be identified with regards to whether an object is the trigger for or the result of a specific action or sequence of actions, namely *input objects* and *output objects*. An important characteristic of an information object is its *priority*, which reflects the extent to which the information carried by the object is critical to the operation of the processes under investigation and the speed with which it has to be processed.
- *Task* – a unit of work carried out by the people involved in the ICT management processes. A task is oriented at processing a predefined (set of) input object(s) and produces a (set of) output object(s) depending on the type and characteristics of the input. In this way, the arrival of an (input) information object serves as a trigger for carrying out a task. Each task consists of one or more logically related *activities*. An activity being an atomic action carried out by a person involved in the ICT management processes. The number of activities of which a task consists depends on the complexity of the required processing and the way in which the task is defined within the processes. In case a task consists of only one activity, the task is equivalent to that activity and they carry the same name. The exact activities to be carried out as part of a task and their sequence depend on the characteristics of the processed input object(s). The order in which tasks and their

related activities are carried out is determined by the priority of the processed object. A typical characteristic of tasks and activities is that they require a certain amount of time to be carried out, causing a certain *delay* in the process chain. Other important characteristics of tasks and activities are the rules, which are used to determine whether a specific information object is a legitimate input to a task and/or activity, and which transformations of this object have to be carried out in order to produce the necessary output.

- *Equipment* **-** the collection of hardware, software and communication facilities, which enable the workers in the IT organization to perform their tasks. Examples of hardware equipment include personal computers, servers, terminals and printers. The software equipment includes operating systems, system management software and application software necessary for carrying out certain tasks and/or activities. The communication equipment includes stationary and mobile telephones, pagers and beepers. The different kinds of equipment are used to process information objects, which results in changes in one or more of their characteristics. The characteristics of the equipment, e.g., availability, processing speed and response time, play a crucial role for the effectiveness and efficiency of the work carried out as part of ICT management.
- *Workplace* – a workplace represents an organizational grouping of logically related tasks and the necessary equipment to carry them out. Defined in this way, a workplace consists of a group of tasks and contains a number of equipment items, and must be seen more as a structural element of the ICT management processes and an organizational unit, rather than a modeling abstraction of the physical places where people carry out their tasks. Defining the concept of *workplace* in this way helps to model situations where people change the set of tasks and the necessary equipment to carry them out on a regular basis, or situations where several persons carry out the same tasks and use the same (type of) equipment. The workplace is the place in the process where the information objects are processed. For each workplace the set of legitimate input objects and the produced output objects can be defined, as well as the order and priority of the tasks carried out there.
- *IT worker* – represents a person working at a specific workplace in the organization. This concept reflects the physical place where a person carries out a specific set of tasks using specific equipment. This equipment can be workplace-dependent, i.e., part of the workplace, as well as workplace-independent, i.e., not part of any specific workplace. In line with the definition of a workplace provided above, several IT workers can work at the same workplace, thus carrying out the same tasks and using the same (type of) equipment.

The concepts defined above and their relationships are depicted in fig. 4.1. In the figure, the concepts are represented by rectangles and their relationships are represented by directed connectors carrying a description of the specific relationship. For example, the relationship between the concepts *information object* and *task* depicted in the figure should be read as “an information object triggers a task”.

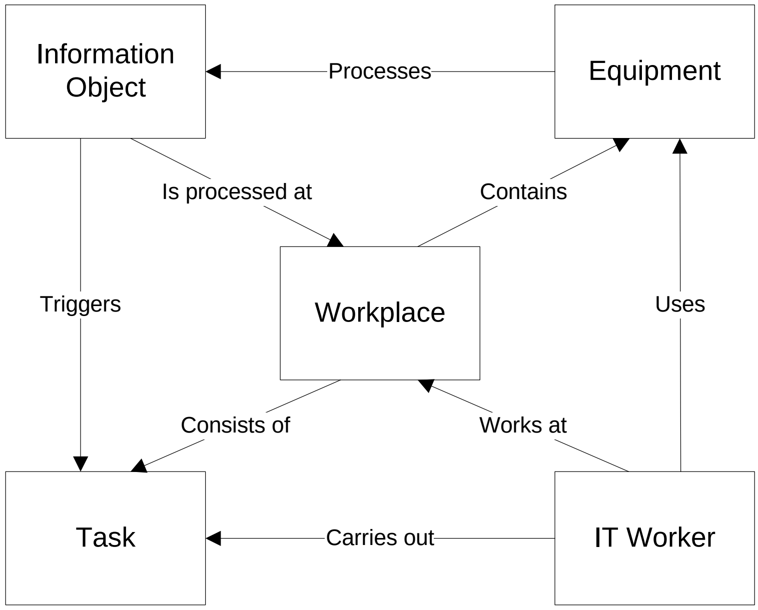

Figure 4.1: The concepts and their relationships

The concept definitions presented above, although informal, provide the basis for the definition of the library of object classes for simulating ICT management processes described in the next sections. Elaboration and formal specification (where necessary) of these concepts is provided in subsequent parts of this text.

4.3 A Library of Object Classes for Simulating ICT Management Processes

As discussed in chapter 2, object-oriented techniques are very suitable for modeling and simulating real-life processes, and are considered by some authors to be even “inescapable” in the area of simulation, offering a way to arrive at a description and the clearest possible understanding of the behavior of the system (or, in our case, the ICT management processes) under investigation (Hill, 1996).

One of the big advantage of using object-oriented techniques in simulation is related to the natural correspondence between the elements of the processes under investigation and the simulation objects used to model them, which can assist in achieving a (formal) description of these processes suitable for developing a simulation model, and facilitate to a large extent the building of the computer representation of the model (Roberts and Dessouky, 1998).

Another advantage of using object-oriented techniques in simulation is the fact that they facilitate component-oriented model development. This means that a simulation model is constructed and built in such a way that it consists of a number of separate components and the implementation of each of these components is largely independent on the implementation of the other components. Many authors have recognized the benefits of using a component-oriented approach in the development of different kinds of software systems (see, e.g., Coad and Yourdon, 1991; Rumbaugh, 1991; Booch, 1994; Jacobson et al., 1995; Bennett et al, 1999; Herzum and Sims, 2000; Szyperski et al, 2002; Apperly, 2003). These benefits include the reuse of existing components, reduced development time, as well as improved manageability, maintainability and reliability of the developed software system. In the area of simulation modeling this translates to reusing the results obtained from previous simulation studies in the same problem domain, reducing the time and improving the quality of the building, verification and validation of a simulation model, as well as facilitating the modeling of larger and more complex systems (Haigh, 2001).

In order to capitalize on the advantages offered by using object-oriented techniques in simulation and facilitate the consistency and reusability in building simulation models of ICT management processes, a set of modeling constructs for the simulation of such processes was specified in the form of a library of object classes based on the concepts described in the previous paragraph. This entailed three main phases. First, in order to define an initial set of simulation object classes a conceptual object model of the problem domain was developed based on the conceptual framework presented above. This is described in sub-paragraph 4.3.1. Second, several new classes were added in order to facilitate the use and extensibility of the library, and its design was defined, while paying special attention to the modeling of the interactions taking place at the workplace. This is described in sub-paragraphs 4.3.2 and 4.3.3 respectively. Third, the library was implemented as a simulation template in the *ARENA*® visual simulation environment, and the classes were implemented as modules within the template. This, together with the parameters made available to the simulation modeler for configuring the characteristics and behavior of the different modules, is described in sub-paragraph 4.3.4.

4.3.1 A Conceptual Object Model of the Problem Domain

The conceptual object model of the problem domain was developed in order to define an initial set of classes for the object class library and specify their attributes, methods and relationships. This was achieved by employing object-oriented analysis techniques (Coad and Yourdon, 1991; Dillon and Tan, 1993; Booch, 1994). Among the goals of object-oriented analysis are to find classes and objects and define their attributes and methods, as well as to identify and specify the relationships between them in such a way so that they provide the required behavior. As a result of this, based on the concepts described in the previous paragraph five basic object classes for the simulation of ICT management processes were defined. These were the classes *Information object*, *Task*, *Equipment*, *Workplace* and *IT Worker.* These classes and their attributes and methods are described in the next sections.

Information object

This class represented the information objects* exchanged within and among ICT management processes and contained information about relevant characteristics of these objects, among which the type of the information object, its origin and destination and the data it carried.

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* The term *information object* is used here to denote the corresponding process element defined in the previous chapter, and should not be confused with the term *object* used to denote an instance of an *object class* in the object-oriented terminology.

Five attributes were specified for this class. These were the *name*, *sender*, *destination*, *type*, and *information* attributes. The *name* attribute represented the identifier of the information object used to distinguish it from other information objects in the processes under investigation. The *sender* and *destination* attributes carried information about respectively the origin and the destination of the information object. The *type* attribute carried information about the type of the information object, e.g., a message, report, e-mail or a phone call. The *information* attribute was used to contain data relevant to the specific type of information object.

Due to the fact that this class represented a passive process element (i.e., an element that exposed no independent behavior of its own and was rather acted upon by other process elements), no methods were defined for it.

Task

This class represented the different tasks carried out as part of the ICT management processes under investigation. It contained information about the activities that were carried out as part of a task, their corresponding durations and the conditions associated with them.

Four attributes were specified for this class. These were the *name*, *activities*, *durations* and *conditions* attributes. The *name* attribute represented the identifier of the task used to distinguish it from other tasks in the processes under investigation. The *activities* attribute contained an ordered list of the activities carried out as part of the task. The attribute *durations* contained an ordered list of durations corresponding to the specified activities. The attribute *conditions* contained an ordered list of conditions corresponding to the specified activities which was used to determine whether a specific activity could be carried out.

Due to the fact that this class represented a passive process element, no methods were defined for it.

Equipment

This class represented the different kinds of equipment used in the ICT management processes. It contained information about the characteristics of the equipment and the functionality necessary to carry out user requests and process information objects.

Three attributes were specified for this class. These were the *name*, *type* and *processing time* attributes. The *name* attribute served to identify a concrete piece of equipment and distinguish it from other equipment in the processes under investigation. The *type* attribute carried information about the type of the equipment modeled, e.g., a PC, a server or a telephone. The *processing time* attribute contained information about the duration of the processing carried out by a concrete piece of equipment in order to produce the desired result or service.

Three methods were defined for this class. These were the *ReceiveRequest*, *CarryOutRequest* and *SendResult* methods. The *ReceiveRequest* method implemented the logic necessary for receiving the requests for processing, determining whether they could be served and for determining the type of processing that had to be carried out. The *CarryOutRequest* method was responsible for carrying out the requested processing, as well as for changing the characteristics (attributes) of the processed information object in order to reflect the results of this processing. The *SendResult* method was responsible for sending the processed information object to the correct destination.

Workplace

This class represented the workplaces, which were part of the ICT management processes under investigation. It contained information about the tasks carried out at a specific workplace and offered the functionality necessary to process information objects which included selecting and carrying out the appropriate task and sending the result to the correct destination.

Four attributes were defined for this class. These were the *name*, *tasks*, *priority rule* and *equipment* attributes. The attribute *name* represented the identifier of the workplace and served to distinguish the workplace from other workplaces in the processes under investigation. The attribute t*asks* contained a list of the tasks carried out at a specific workplace. The attribute *priority rule* represented the rule used to choose the information object to be processed. The attribute *equipment* contained a list of the items of equipment available at a specific workplace.

Six methods were defined for this class. These were the *ReceiveInformationObject, SelectTask, CarryOutTask, RequestProcessing, ReceiveResult* and *SendInformationObject* methods. The *ReceiveInformationObject* method was responsible for receiving the information objects arriving at the workplace and selecting the object to be processed according to the priority rule used at the workplace. The *SelectTask* method was responsible for selecting the task to be carried out. The *CarryOutTask* method was responsible for determining the activities that had to be carried out as part of the selected task, carrying them out in the correct order and modifying the characteristics of the processed information object (or, if necessary, creating a new information object) in order to reflect the results of the processing. The *RequestProcessing* method was used as part of the *CarryOutTask* method for sending requests for processing to the equipment included in the simulation model. The *ReceiveResult* method was responsible for receiving the results of the requested processing and directing them to the place (at the workplace) where their processing continued. Finally, the *SendInformationObject* method was responsible for sending the processed information object to the appropriate destination within the simulation model.

IT Worker

This class represented the IT workers involved in the ICT management processes under investigation. It contained information about the workplace the IT worker was working at, as well as about the person who was carrying out the actual processing.

Three attributes were defined for this class. These were the *name*, *workplace* and *worker* attributes. The attribute *name* represented the identifier of the IT worker and served to distinguish it from other IT workers in the processes under investigation. The attribute *workplace* contained information about the workplace on which the IT worker was working. The attribute *worker* carried information about the person carrying out the actual processing

The methods necessary to process incoming information objects were defined in the *Workplace* class. These methods were inherited and used by the *IT worker* class. Therefore, no additional methods were defined for the *IT Worker* class.

The specification of the classes described above and their attributes and methods is given on fig. 4.2.

Object class *Information Object*

Attributes
Name
Sender
Destination
Type
Information

Object class *Task*

Attributes
Name
Activities
Durations
Conditions

Object class *Workplace*

Attributes
Name
Tasks
Priority rule
Equipment

Methods
ReceiveInformationObject
SelectTask
CarryOutTask
RequestProcessing
ReceiveResult
SendInformationObject

Object class *IT Worker*

Attributes
Name
Workplace
Worker

Object class *Equipment*

Attributes
Name
Type
Processing time

Methods
ReceiveRequest
CarryOutRequest
SendResult

Figure 4.2: The specification of the basic classes

The five classes described above were used to develop the conceptual object model (Dillon and Tan, 1993; Booch, 1994; Cook and Daniels, 1994; Fowler and Scott, 1997) of the problem domain. This model was developed in the form of a class diagram built in line with the notation described in (Booch, 1994). A (simplified) set of symbols of this notation is depicted in fig. 4.3. This notation offers a graphical representation necessary to communicate the ideas presented as part of this thesis, however, in the course of the research UML has gained popularity as a tool for object-oriented modeling and is used increasingly as the methodology of choice in object-oriented analysis and design. Therefore, in appendix A the class diagrams presented in this and the following chapters are depicted using UML notation.

The class diagram representing the conceptual object model is depicted in fig. 4.4. As it can be seen from the figure, the conceptual model encompasses the five classes described above and their relationships. These relationships can be specified as follows:

- An *association* relationship was defined between the classes *Task* and *Information Object.* This reflects the fact that information objects serve as the input and output of tasks and their state can be altered during the execution of a task. The relationship is “many-to-many as the same information object can serve as an input or output for several tasks, and one task can have more than one input and/or output objects

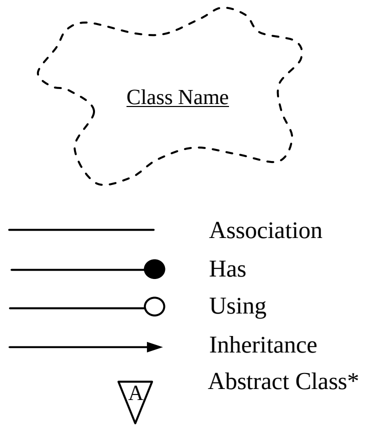

Figure 4.3: The object diagram notation

- An *association* relationship was defined between the classes *Information Object* and *Equipment.* This reflects the fact that information objects are processed by the different pieces of equipment used in the ICT management processes. This association is “many-to-one” as one information object can be processed by only one piece of equipment at a certain point in time, while one piece of equipment can process several information objects simultaneously.
- A “many-to-many” *using* relationship was defined between the classes *Information Object* and *IT Worker.* This reflects the fact that IT workers use information objects to exchange information for the purposes of communication and coordination. One IT worker can use many information objects, and one information object can be used by several IT workers simultaneously.
- A “many-to-one” *association* relationship was defined between the classes *Information Object* and *Workplace*. This reflects the fact that information objects are processed at workplaces, and one information object can be processed at only one workplace at a certain point in time, while several information objects can be processed concurrently at a given workplace depending on the task carried out.
- A *whole-part* relationship was defined between the class *Workplace* and the classes *Equipment* and *Task.* This reflects the fact that, in line with the class definitions provided above, each workplace has a set of tasks, which are carried out there and a set of equipment used to carry out these tasks. Both relationships are “many-to-many” as more than one task can be carried out at a given workplace, one and the same task can be carried out at more than one workplace, more than one piece of equipment can be used at a workplace, and a certain piece of equipment can be used by several workplaces simultaneously.
- A “many-to-many” *association* relationship was defined between the classes *Task* and *IT Worker*, reflecting the fact that IT workers carry out tasks as part of the ICT management

* The use of the *Abstract Class* icon is described in sub-section 4.3.2.

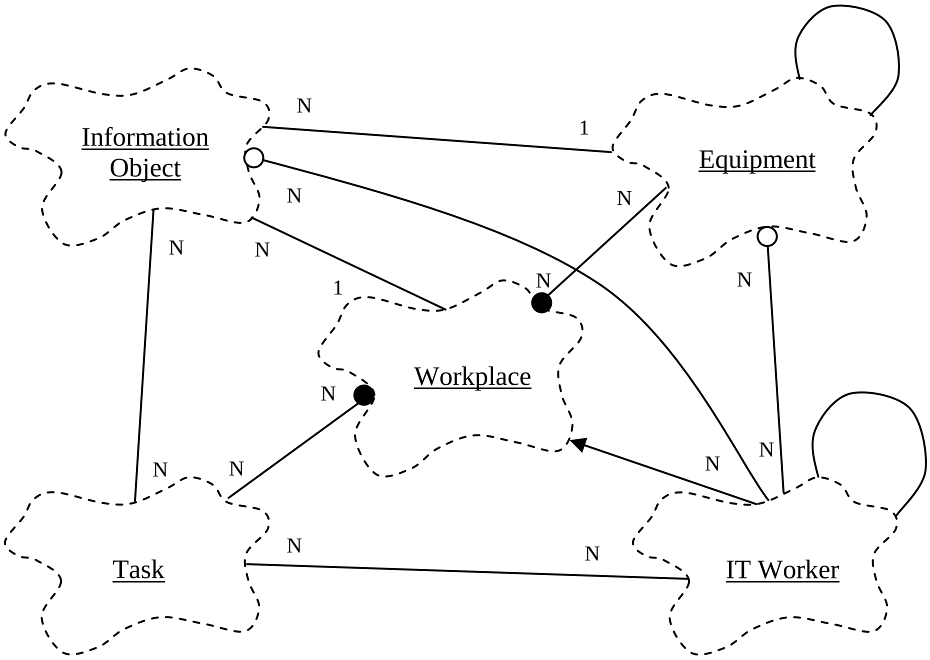

Figure 4.4: The conceptual object model of the problem domain

processes they are involved in. One IT worker can carry out several tasks concurrently, and one and the same task can be carried out by several IT workers simultaneously.

- An *inheritance* relationship was defined between the classes *IT Worker* and *Workplace*. As mentioned above, an IT worker inherits the characteristics, tasks and methods of the *Workplace* class, adding to them information about the person working at the workplace.
- A *using* relationship was defined between the classes *IT Worker* and *Equipment*, reflecting the fact that IT workers use different kinds of equipment in their work. This relationship was defined as "many-to-many", as one IT worker can use different pieces of equipment simultaneously, and one piece of equipment can be used by several IT workers at the same time.
- A *using* relationship exists between the classes *IT Worker* and *Equipment*, reflecting the fact that IT workers use different kinds of equipment in their work. This relationship is "many-to-many", as one IT worker can use different pieces of equipment simultaneously, and one piece of equipment can be used by several IT workers at the same time.
- A recursive *association* relationship was defined for the classes *IT worker* and *Equipment* (denoted by the loop on the class icon) reflecting the fact that the instances of these classes they often work in close cooperation with other IT workers and pieces of equipment respectively.

4.3.2 The Design of the Object Class Library

The conceptual object model of the problem domain was used as a basis for developing the design of the library of object classes for simulating ICT management processes. This design was developed taking into account the specific characteristics of the *ARENA*® simulation environment (described in sub-section 4.3.4) in which the library was implemented. As a result of this, six *additional classes* were defined and *the structure of the object class library* was specified. This is described in the next sections.

Additional Classes

In order to improve the structure and facilitate the use and the extensibility of the library six additional classes were defined. These were the *Employee, Personnel, Tasks Collection, Personal Computer*, *Telephone* and *Server* classes.

The class *Employee* represented the persons involved in the processes under investigation. Two attributes were defined for this class: *name* and *skill level.* The attribute *name* carried information used to uniquely identify the person in the processes under investigation. The attribute *skill level* carried information about the extent to which the IT worker had mastered his/her tasks and could be used to calculate the time which the worker needed to carry out a certain task and/or activity.

The classes *Personnel* and *Tasks Collection* were defined as collection classes* and provided the means for entering and manipulating information in the model about respectively the people taking part in the processes under investigation and the set of tasks carried out. The reasons for using collection classes within the object class library are, on the one hand, that they provide a convenient way of managing a set of objects of the same kind and, on the other hand, the advantages which the *ARENA*® simulation environment offers for implementing such classes.

The classes *Personal Computer*, *Telephone* and *Server* represented three very common types of equipment used as part of the ICT management processes, and inherited the attributes and methods defined for the class *Equipment*. However, additional attributes were defined where necessary and a concrete implementation of the methods of the class *Equipment* was provided in order to capture the specific characteristics and functionality of the equipment they represented.

The attribute *number* was defined in the class *Telephone* which carried information about the number of a specific telephone set. The methods inherited from the class *Equipment* were redefined in this class so as to provide the logic necessary to represent connecting to a number or receiving phone calls.

No additional attributes were defined in the class *Personal Computer*. However, the methods inherited from the class *Equipment* were redefined in this class so as to provide the logic necessary to distinguish whether the processing requested by the user has to be carried out locally or on a network server, for carrying out the request in the former case or sending the request to the appropriate server and receiving the result in the latter case.

The attribute *capacity* was defined in the class *Server* which carried information about the maximum number of simultaneous connections the server could process. The methods inherited from the class *Equipment* were redefined in this class so as to provide the logic necessary to represent the receiving the requests for processing, carrying them out and sending the result to the correct destination.

The Structure of the Object Class Library

The structure of the object class library is depicted in fig. 4.5. It includes the classes defined as part of the conceptual object model described in sub-section 4.3.1, the six additional classes described above and the relationships among the classes. As it can be seen from the figure, next to the relationships introduced as part of the conceptual object model, several additional relationships were defined. These relationships can be described as follows:

- An *inheritance* relationship was defined between the classes *IT Worker* and *Employee*. This reflected the fact that the class *IT Worker* inherited the attributes defined for the class *Employee* in order to represent the people working at the different workplaces.
- A *whole-part* relationship was defined between the classes *Task* and *Employee* and their collection classes *Tasks Collection* and *Personnel* respectively. This reflected the fact that the latter two consisted of items of the former two. The relationship was defined as "one-to-many" as one employee or task can belong to only one personnel or task collection class respectively, while the collection classes could contain many employees or tasks.
- An *inheritance* relationship was defined between the classes *Personal Computer*, *Telephone* and *Server* and their parent class *Equipment.* This reflected the attributes and methods which the three additional classes inherited from their parent class.

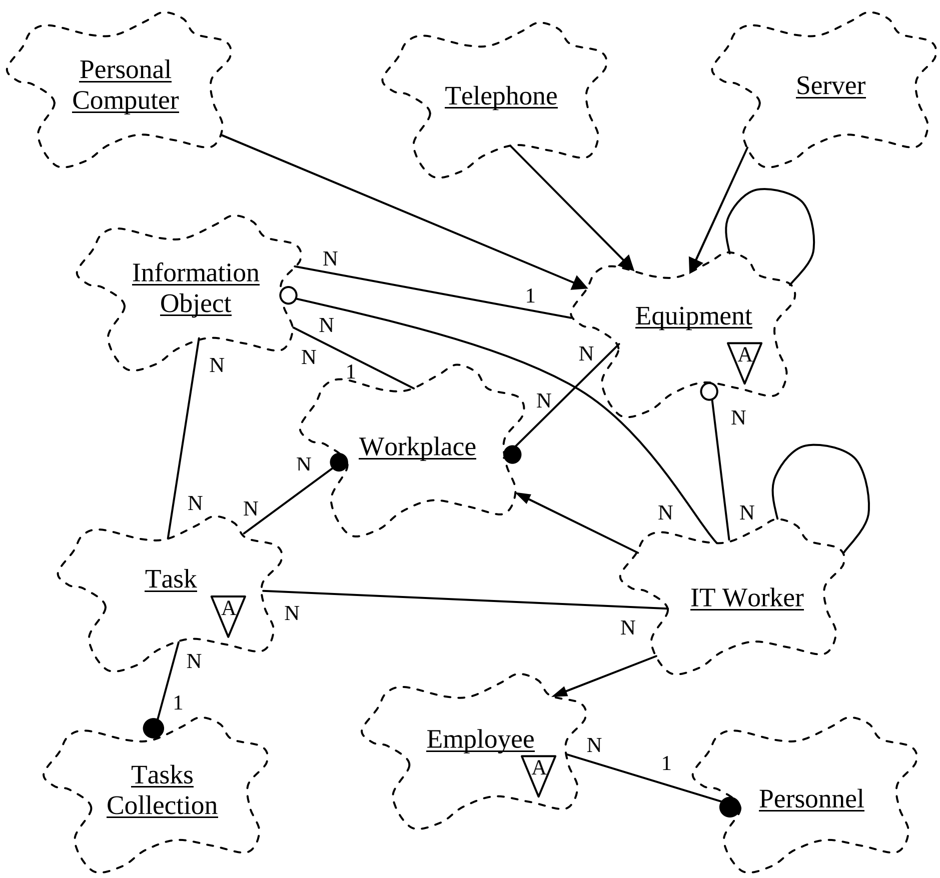

Figure 4.5: The structure of the object library

The classes *Equipment*, *Task* and *Employee* were defined as abstract classes. Abstract classes are classes that have no direct instances, and are rather meant to provide a template for classes derived from the abstract class (Blair et al, 1991; Champeaux et al, 1993; Booch, 1994; Fowler and Scott, 1997; Bennet et al, 1999; Oberg et al, 2003). In this way, abstract classes are used as repositories for attributes and methods shared by classes of a certain type. Typically, abstract classes contain data definitions and abstract methods (i.e., methods, which do not contain any implementation-specific characteristics).

Having this in mind, we defined the three classes mentioned above as abstract within the object class library in order to provide a generic definition of the attributes and methods necessary to capture the characteristics and behavior of the elements they represent. As these classes cannot have direct instances, further specification of their methods was necessary before they could be used in a simulation model. For the class *Equipment* this specification was achieved through the child (derived) classes *Personal Computer*, *Telephone* and *Server*, and for the classes *Employee* and *Task* – through the corresponding collection classes *Personnel* and *Tasks Collection* which provided the methods and interfaces for entering and managing the class data.

As mentioned in the beginning of this sub-paragraph, the design of the library of object classes was developed taking into account the specific characteristics of the simulation environment in which it was implemented. By implementation in other development or simulation environments some of the classes may not be necessary or their characteristics and behavior may need to be changed and new classes may need to be introduced.

4.3.3 Workplace Interactions

The most complex class from the ones presented above in terms of working logic and implementation was the *Workplace* class. Therefore, in this sub-paragraph more information is provided on several important aspects of the work at the workplace (fig. 4.6) and the way in which they are modeled is discussed.

An important aspect of the work at the workplace was the selection of the information object that had to be processed and the appropriate task(s) to be carried out. This selection was often based on the urgency or priority of the information object. This is a relatively static characteristic of the object, and its value is determined mostly in the process of designing the simulation model. However, other factors like deadlines for processing the object, existing dependencies among the objects to be processed, or other restrictions in the processes under investigation can also play a role in the selection process. Therefore, the actual selection of the object to be processed was based on a dynamic priority, which was calculated at the workplace every time an information object arrived. As the algorithm for calculating this priority depended on the concrete situation to be simulated, an opportunity was provided to define this algorithm for the different workplaces.

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* A *collection class* is a class that is specifically developed for managing a set (collection) of objects. It usually encapsulates the data and methods necessary to add, modify and remove objects of a specific type. For more information on collection classes see, e.g., (Kurata, 1999).

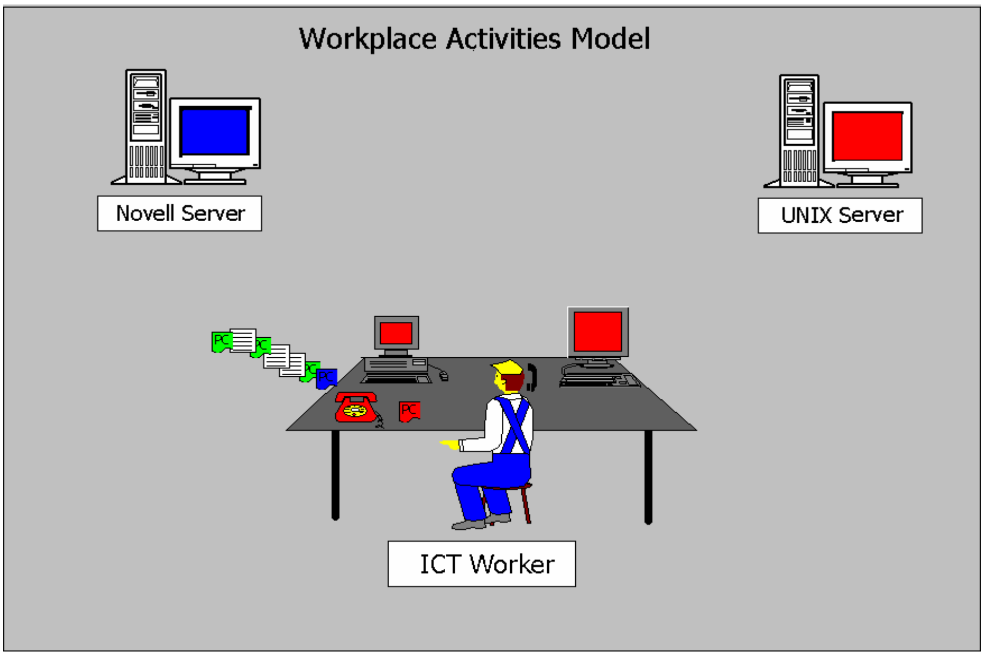

Figure 4.6: The work at the workplace

Another important aspect of the work at the workplace which had to be captured and modeled was the interruption of the execution of a task or activity. Such an interruption occurs very often in real-life processes and can have various reasons/sources, e.g., an incoming phone call, a person entering the room with a question, or the occurrence of an event requiring immediate action. Many of the simulation languages currently available at the market offer tools (language constructs) for modeling the interruption of the work of a resource. However, in many cases additional measures have to be taken by the simulation modeler in order to save the state of the interrupted resource. Explanations with regards to this are given in the following sections where necessary.

With regards to the use of equipment in order to carry out a certain task or activity, a distinction can be made among several categories of activities. Assuming that the basic types of equipment used are a telephone and a computer (which can be used as a standalone PC, or it can have connections with other equipment like servers and printers), we have defined three basic categories of activities carried out at the workplace. These are *office activities*, *telephone activities*, and *computer activities*.

No special equipment is needed to carry out the *office activities*. These activities can model for example the work associated with studying printed documents. In case such an activity is interrupted, saving information about the processed information object and the percentage of the work done will in the most cases be sufficient for restoring the state of the activity at a later moment. One aspect, however, which may need to be captured is the increase in the overall processing time for an office task in order to capture the additional time which is necessary in order to restore the work to the original state when it was interrupted (e.g., it could be necessary to re-read some sections of the document after the interruption). This *restoration time* can be considerable in some cases depending on the length of the interruption, and in case of multiple interruptions can have an influence on the overall performance of the processes under investigation.

The *telephone activities* have two variations: making a phone call and receiving a phone call. Making a phone call is an activity, which is left at the discretion of the person carrying it out and can be synchronized and modeled as part of the activities consisting a certain task. Receiving a telephone call, however, is asynchronous and can occur at any moment during the execution of a task or activity, causing an interruption of this execution. This interruption occurs almost in all cases, even if the processing carried out is of critical importance. One of the ways to model this is to represent the incoming call as an event with a high priority in the simulation model. Measures have to be taken for saving the state of the task/activity which is being carried out, and for restoring this state after the end of the call. Due to the usually short duration of phone calls, the recovery time associated with them is negligible.

The *computer activities* can be modeled as sending a request to a certain computer resource, and receiving and processing the result. With regards to the moment of receiving the result and its processing, a distinction can be made between two types of activities: send a request and wait until the answer is received (synchronous), or send a request and do not wait for the answer, continuing the work with other activities (asynchronous). The answer in the latter case is received at a later moment and processed as a normal information object, possibly taking into account its specific character when calculating its priority. However, if the used computer functions as a simple terminal, which redirects the requests of the user to a server and returns the received result, it will not be possible to use it before the server has returned the result for the requested processing. On fig. 4.7 the interaction diagrams (Booch, 1994; Fowler and Scott, 1997) are depicted for the *wait* and *no-wait* types of activities in the cases where the computer functions as a terminal (*a* and *b*) and a PC (*c* and *d*) and is connected to a back-end server. In this way, cases (*a*) and (*b*) depict the situations where the computer functions as a terminal and requests processing from a server. In the first case the IT worker waits until the processing has completed and the server has returned a result. In the second case the IT worker continues with processing other tasks after sending a requests for processing to the server, however, the terminal session remains busy until a result is received from the server. The difference between cases (*c*) and (*d*) is similar, however, in the latter case the PC does not remain busy until an answer is returned and can be used for other activities.

The workplace activities described in this section can be identified in the work of various workplaces in different ICT management processes. Therefore, they can be used for defining *workflow patterns* (van der Aalst et al, 2003). These patterns can then be used with different workflow languages for achieving workflow specifications of ICT management processes that can be implemented in workflow management systems for the analysis and support of such processes.

4.3.4 The Implementation of the Object Class Library

The library of object classes (depicted on fig. 4.5) was implemented as a template for simulating ICT management processes in the *ARENA*® (Rockwell Software, 2000) simulation environment (for a comprehensive overview and comparison of the available simulation software see, e.g., Swain,1999). *ARENA*® is a visual environment based on the constructs of the *SIMAN* simulation language. It provides a graphical interface for using these constructs, as

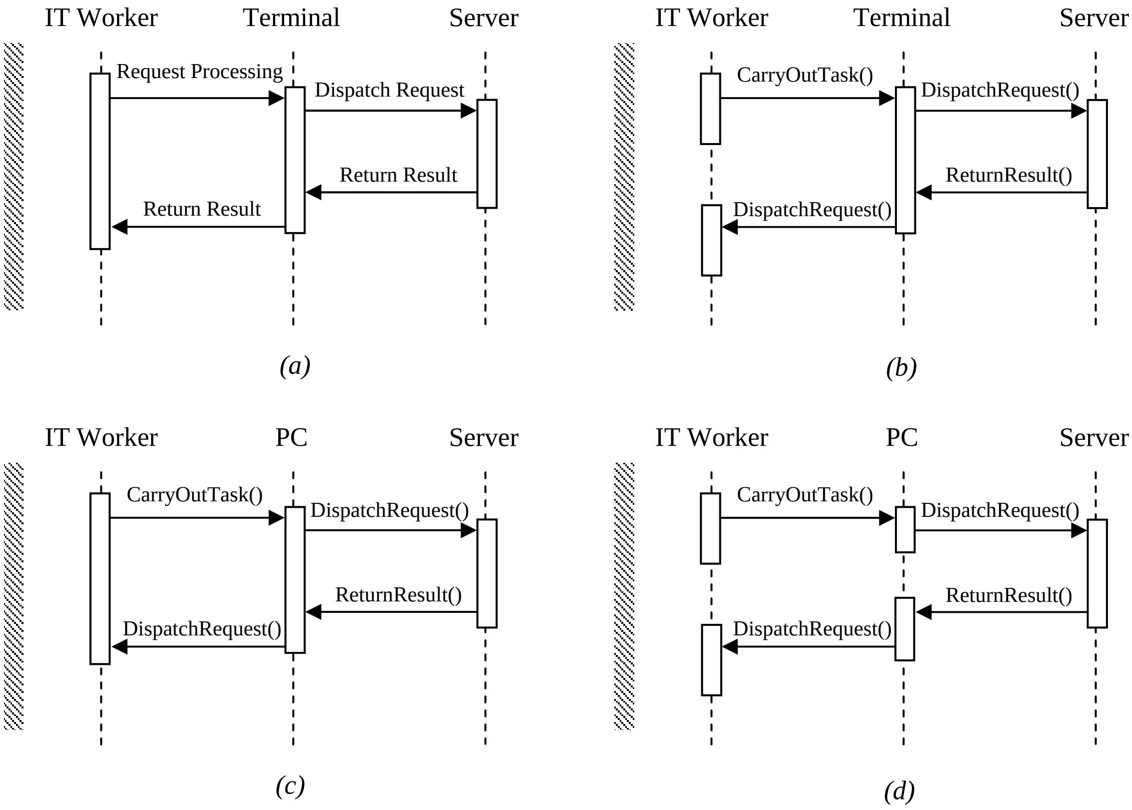

Figure 4.7: Interaction diagrams of computer activities at the workplace

well as means to integrate code written in *Visual Basic* or *C++* in a simulation model. It also incorporates advanced tools for analysis and graphical representation of input and output model data and has rich capabilities for interactive animation of the work and status of simulation models.

The choice of *ARENA*® for implementing the object-class library was to a significant extent based on the fact that it was successfully used for building an ICT management simulator as part of the research program on ICT management simulation of the chair *Information Strategy and Management of Information Systems* of the Department of Information Systems Management, Faculty of Information Technology and Systems of the Technical University Delft. This, together with the developed modeling constructs and the gained expertise in working with *ARENA*® when building these models proved to be a strong argument when choosing this package for this research.

One of the most useful features of *ARENA*® is the possibility it offers for building and using user-defined simulation templates. A simulation template is a library of modeling constructs called *modules*, which offer some kind of simulation functionality. The use of templates allows for capturing knowledge and storing simulation objects and constructs for a specific domain of interest. It also promotes their sharing and reuse, thus contributing to reducing the development time and improving the quality of simulation models.

The functionality and characteristics of the modules contained in the different templates can be configured for each particular case by means of module parameters, called *operands*. The values of these operands can be changed in the so-called *operand window*, which forms the user interface of the module. The work of the module in the simulation model can be animated by using the *user view* of the module. This user view can be changed to reflect the specifics of a concrete simulation model. The internal logic and working of the module are hidden to the user. In this way, a module is an animated "black-box" component, which can be configured through the user interface and can be used as a building block in a simulation model.

With regards to the programming of object-oriented simulation models, *ARENA*® does not provide direct support for implementing object orientation and can be rather qualified as an object-based environment (Joines and Roberts, 1999). Aspects like inheritance, association or encapsulation cannot be directly implemented in a simulation model or in the modules of a simulation template. Variables defined in one module can be accessed from all parts of the model where the module is used. This can be compensated to some extent by defining module-specific variables, which can reduce the probability of unintentional use of the variables. In order to implement inheritance, the parent module must be included in the child module, and the latter must be extended with the desired functionality. This is compensated to some extent by the fact that a separate "operand space" is allocated to each module, and in this way the operands of a module are not "visible" to other parts of the model. The possibility for integrating code written in Visual Basic and C++ can also be used as a workaround for this shortcoming.

However, the shortcomings of *ARENA*® with regard to object orientation refer only to actual coding of the programs of the simulation models, while many authors in the field of object-oriented analysis, design and programming (e.g., Coad and Yourdon, 1991, Booch, 1994) share the vision that the main benefits of using object orientation are reaped in the stages of analysis and conceptual modeling of the problem domain, and that the implementation is language-independent and can be carried out in most of the existing programming languages, although the efficiency of this implementation will be higher if an object-oriented language is used. In this line of thought, implementing an object-oriented model in *ARENA*® is not so efficient in terms of coding the simulation objects and their relationships as it is in an environment offering direct support for object orientation. Nevertheless, it still offers the main benefits of object orientation to the end-user, i.e., the possibility to model a system in a way which reflects the actual objects of which the system consists and their characteristics, behavior and interrelationships, as well as possibility to use ready-made constructs for model development, the implementation of which is hidden and which represent and mimic the behavior of real-world objects of the system or processes under investigation. This point of view is also supported by the fact that implementations of object-oriented simulation models in *ARENA*® are reported in the literature (see, e.g., de Vreede, 1995 and van Eijck, 1996). Therefore, we consider this environment as suitable enough for implementing the object class library described here.

The object classes described in fig. 4.5 were implemented as modules in a template for the simulation of ICT management processes. For each module a set of operands was defined based on the attributes of the corresponding class. These operands were used to configure the characteristics and functioning of the respective module. Modifications to these operands could be made through the operand window of the module. The methods of the classes were implemented as part of the module logic. The user view of the modules was adjusted in order to reflect the function of the module. A concise description of the implemented modules is provided in the sections that follow.

The class *Information Object* was implemented as a module defining an entity, which represents the information objects in the model. The attributes *name*, *sender*, *destination*, *type* and *information* were defined in this module. A possibility was provided for defining new attributes by the simulation modeler. This is depicted on fig. 4.8. Due to the fact that *ARENA*® provides convenient tools for assigning animation pictures to entities, and consequently – to the different information objects in the model, no special measures were taken to change the user view of this module.

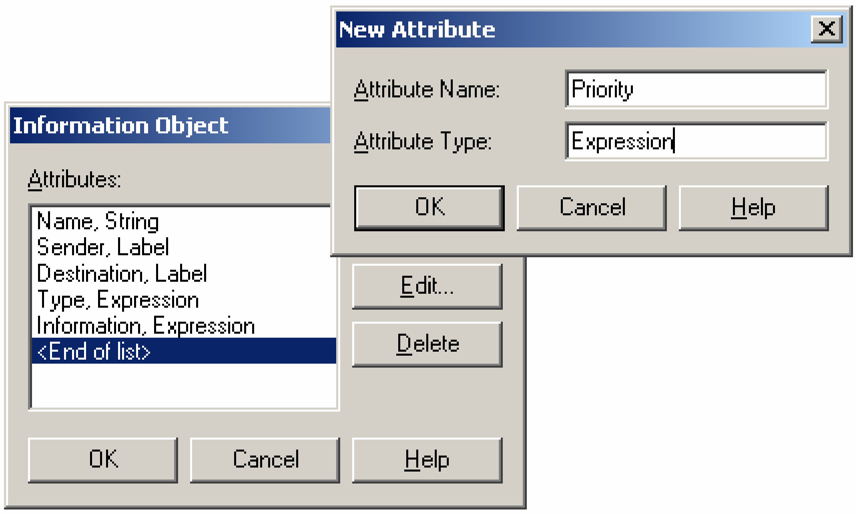

Figure 4.8: The operand window of the *Information Object* class

The module *Task* defined the attributes and data structure necessary for defining tasks in the model according to the specification provided for the corresponding class. As this module represented an abstract class, it was defined as a module, which cannot be explicitly used in a simulation model and was used only for defining other modules.

The module *Task Collection* represented the corresponding collection class defined in sub-section 4.3.2. It was based on the definitions provided by the *Task* module and provided the data structures necessary for storing task information and making this information available to other parts of the simulation model. Through its operand window the module provided means for defining and modifying tasks, their constituent activities and the corresponding durations and conditions. As there was no need to animate the tasks in the model, no special actions were taken to modify the user view of this module. The operand window of the *Tasks Collection* module, as well as the dialog boxes for defining new tasks and activities are shown on fig. 4.9.

The implementation of the modules *Employee* and *Personnel* was similar to the implementation of the modules *Task* and *Tasks Collection*.

The module *Employee* defined the attributes described in the specification of the corresponding class described in sub-section 4.3.2. As the module represented an abstract class, it was defined as a module, which cannot be explicitly used in a simulation model and was used only for defining other modules.

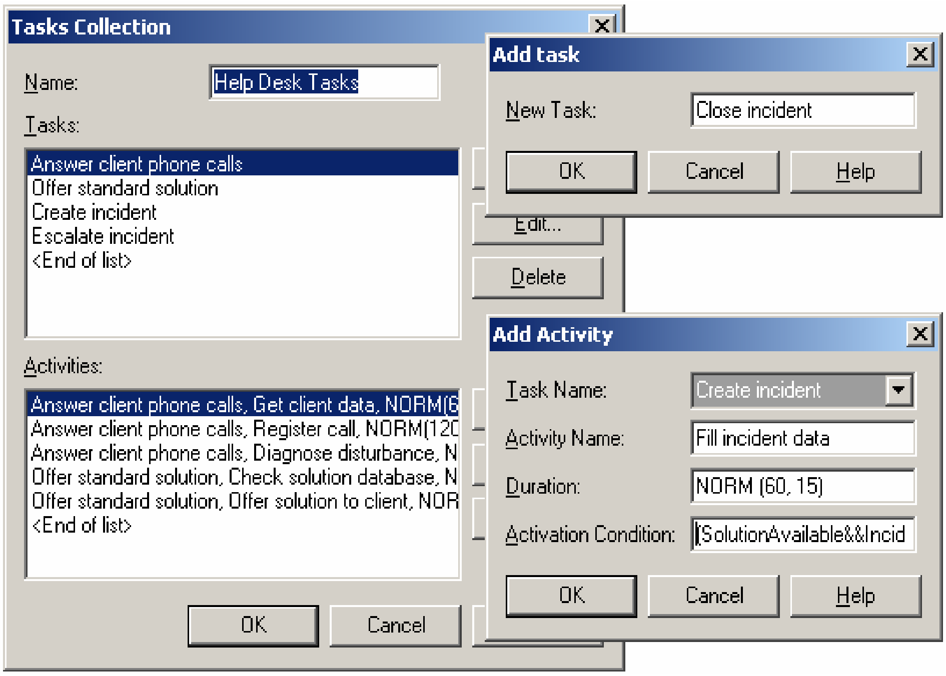

Figure 4.9: The operand window of the *Tasks Collection* class

The module *Personnel* represented the corresponding collection class described in sub-paragraph 4.3.2. It was based on the definitions provided by the *Employee* module and provided the data structures necessary for storing employee information and making this information available to other parts of the simulation model. Through its operand window the module provided means for entering and modifying information about employees taking part in the processes under investigation. The operand window of the module *Personnel* and the dialog for entering employee information are shown in fig. 4.10.

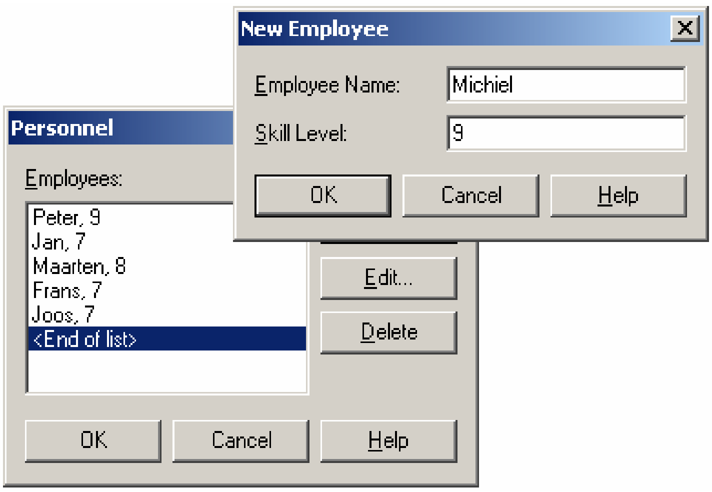

Figure 4.10: The operand window of the *Personnel* module

The module *Equipment* implemented the attributes and methods of the corresponding class defined in sub-paragraph 4.3.2. As the module represented an abstract class, it was defined as a module, which cannot be explicitly used in a simulation model, and was rather used to provide the basic data structure and methods for the modules *Server*, *Telephone* and *Personal Computer*.

The module *Server* modeled the functionality of a server processing user requests. It implemented the attributes and methods of the corresponding class. The attributes *name*, *processing time* and *capacity* could be configured through the operand window of the module depicted in fig. 4.11. The methods of the module redefined the methods of the *Equipment* module so as to enable the changing of the attributes of the processed information object according to the type and result of the carried out processing.

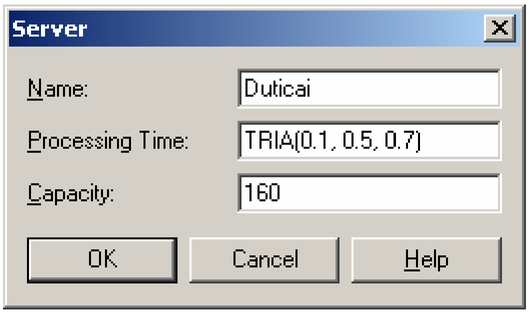

Figure 4.11: The operand windows of the *Server* module

The module *Telephone* modeled the functionality of a telephone set. It implemented the attributes and methods of the corresponding class. The attributes *name* and *number* could be configured through the operand window of the module depicted in fig. 4.12. The methods of the module redefined the methods of the *Equipment* module so as to model the receiving of phone calls and making a connection with a required telephone number.

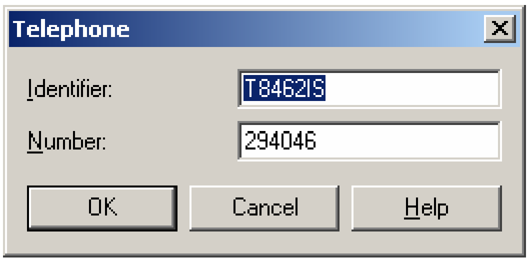

Figure 4.12: The operand windows of the *Telephone* module

The module *Personal Computer* implemented the attributes and methods of the corresponding class described in sub-paragraph 4.3.2. The attributes *name* and *processing time* could be configured through the operand window of the module depicted in fig. 4.13. The methods of the module redefined the methods of the *Equipment* module so as to provide the logic necessary to model the handling of a request for processing and to modify the attributes of the processed information object in order to reflect the results of the processing. A distinction was made between processing carried out locally on the personal computer and processing carried out on a remote server. In the latter case the methods of the module were responsible for sending the request for processing to the correct server and for handling the result according to the type of computer activity (synchronous or asynchronous) as described in sub-paragraph 4.3.3.

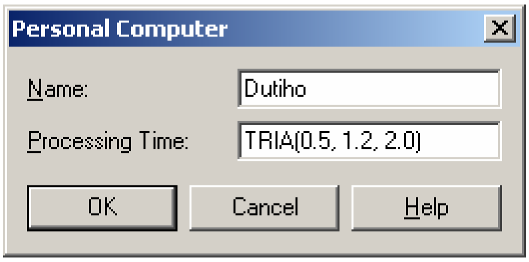

Figure 4.13: The operand windows of the *Personal Computer* module

The module *Workplace* implemented the attributes and methods of the corresponding class described in sub-paragraph 4.3.2. The module provided the basic data structures and means for defining workplace tasks and controlling the way in which the work at a specific workplace is carried out, as well as for configuring the equipment used at the workplace.

Several design decisions were made and implemented in this module with regards to selecting the task to be carried out and the control of its execution. These can be summarized as follows:

- Possibility was given to the simulation modeler to define a selection condition and priority for each task defined at the workplace, thus providing a flexible mechanism for capturing differences in task prioritization and selection at the different workplaces.
- A mechanism and the corresponding interface for its configuration were provided for dynamically calculating the duration of an activity according to the characteristics of the processed information object and the skill level of the person working at the workplace.
- In situations where an asynchronous computer activity (see sub-paragraph 4.3.3) was required to process an information object, measures were taken to ensure that the result of the activity was processed before other waiting information objects with the same priority. However, if there were objects with higher priority, they were processed first.
- In order to control the way in which tasks were executed at a specific workplace, the possibility was provided to change the state of the model by assigning values to model parameters. This was achieved by defining assignments, which were made before or after an activity was carried out. By means of such assignments information object attributes as well as module parameters could be dynamically modified, thus allowing for great flexibility in configuring module behavior.

A standard set of equipment was implemented in the *Workplace* module which included a telephone and a personal computer. A mechanism for configuring their characteristics was provided through the user interface of the module using the parameters of the corresponding *Telephone* and *Personal Computer* modules described above.

The operand window of the *Workplace* module providing the interfaces for entering and modifying the information described above is depicted in fig. 4.14. As it can be seen from the figure, fields are provided for entering the name of the workplace and for defining the task collection it uses. The '*Tasks*' dialog provides means for defining the tasks carried out at the workplace. Through the dialogs '*Assignments Before Processing*' and '*Assignments After*

Processing' assignments can be defined, which have to be carried out before or after the execution of an activity. The dialog buttons '*Configure PC Data*' and '*Configure Telephone Data'* provide the means for configuring the two standard equipment items provided in the module. Finally, a field is provided for defining the destination to which a processed information object will be send, in case this is not taken care of in the processing logic.

The methods of the *Workplace* module implement the logic necessary for handling the input information objects, selecting and executing the different tasks using the necessary equipment, and sending the produced output to the correct destination. They are also responsible for modifying the characteristics of the processed information objects so as to reflect the results of the carried out processing.

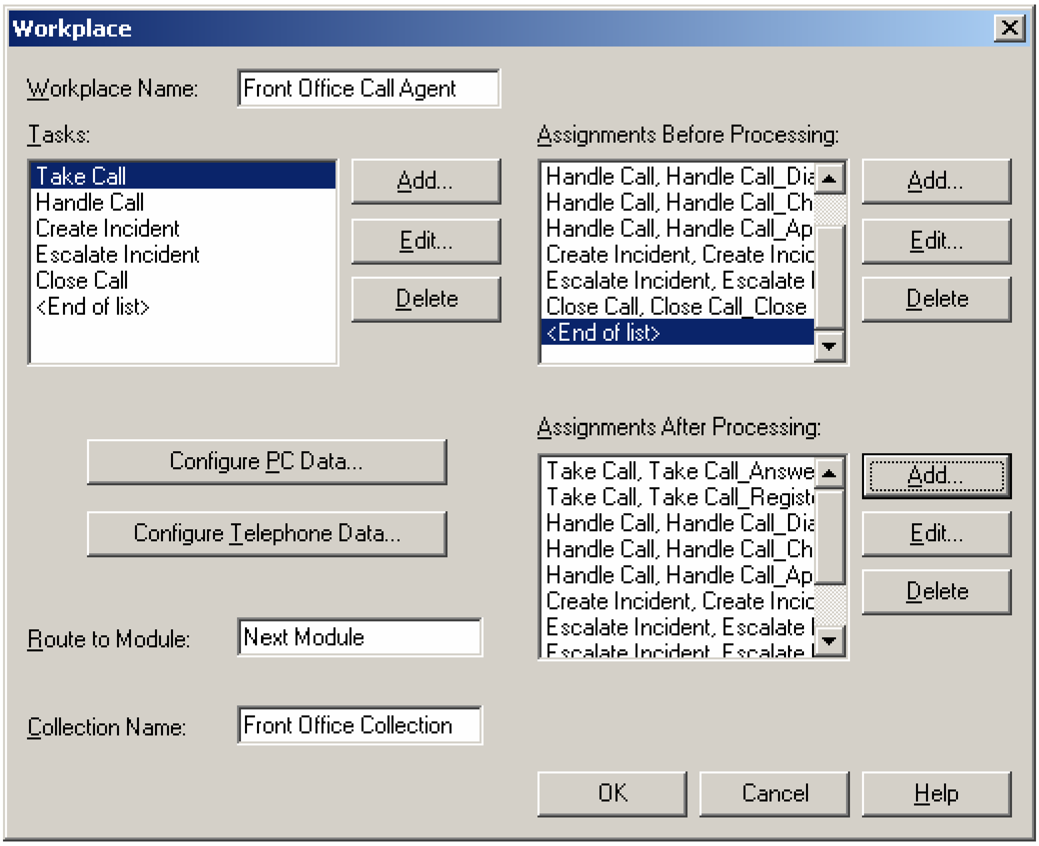

Figure 4.14: The operand windows of the *Workplace* module

As mentioned above, the *Workplace* module provided the basic data structures and means for defining workplace tasks and controlling the way in which the work at a specific workplace is carried out. However, the module did not carry information about the person carrying out these tasks and activities, and did not provide any animation capabilities. Its function was rather to impose a structure and provide the means for building modules, which represent the IT workers taking part in the processes under investigation.

The module *IT Worker* represented the corresponding class defined subparagraph 4.3.2. It used the data structures and methods defined in the module *Workplace,* and added information about the person working at a specific workplace based on the data provided by the *Personnel* module. In line with this, the operand window of the module depicted in fig. 4.15 provided means for configuring the name of the IT worker and selecting the workplace and the person working there. It also offers the possibility to make additional assignments for the specific IT worker.

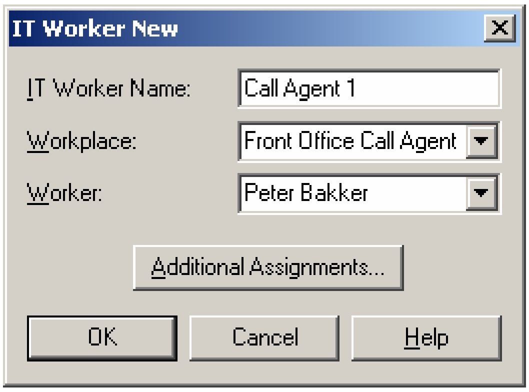

Figure 4.15: The operand window of the *IT Worker* module

The user view of the *IT Worker* module provided the facilities necessary to animate the operation of the module. It included icons visualizing the person working at a workplace and the basic equipment he or she uses. The user view of the module is shown in fig. 4.16.

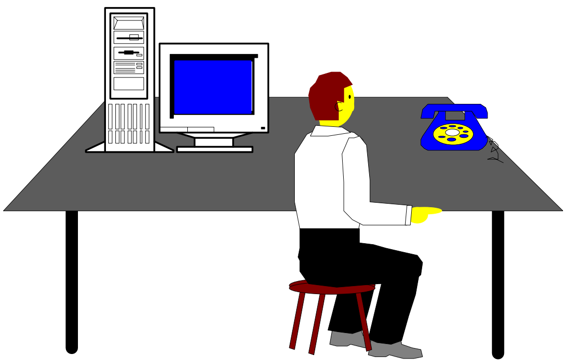

Figure 4.16: The user view of the *IT Worker* module

The simulation template for modeling ICT management processes provides the modules necessary for capturing the functionality of the main elements of these processes and their interactions. It also provides the facilities for visualizing the work of these elements. The functionality and/or animation of the modules can be extended to accommodate specific modeling needs if necessary. However, the template does not provide the logic necessary for capturing the overall structure of the modeled processes, generating the necessary events and the corresponding information objects, and controlling the flow of entities in the model. This logic is highly dependent on the characteristics of the specific situation and should be defined and added to the model for each separate case.

4.4 Conclusions

In this chapter a framework for simulating of ICT management processes was presented, consisting of a conceptual framework and a library of object classes for the simulation of such processes. The conceptual framework comprises a set of concepts for the modeling of ICT management processes based on the generic process elements described in chapter 3. The library of objects classes offers a set of reusable modeling components for building simulation models of ICT management processes, and provides a description of the characteristics, functionality and implementation of the components. In relation to this, the following conclusions about the presented framework for simulating ICT management processes have been made:

- The conceptual framework offers a structured conceptual basis for building simulation models of ICT management processes. It includes concepts based on the generic process elements identified as part of the explorative case described in chapter 3 and provides a description of their basic characteristics, behavior and relationships. This provides a basis for the further specification and use of these concepts for building the conceptual model (discussed in the next chapter) of the processes under investigation.
- A library of object classes for simulating ICT management processes was defined on the basis of the described conceptual framework. The library consists of simulation constructs, which capture the characteristics and behavior of the elements of the conceptual framework taking into account the requirements specified in chapter 3. The constructs provide the means for modeling the tasks and activities carried out as part of the processes under investigation, the workplaces and the people working there, the equipment used, the information flow within the processes and the rules guiding this flow and the work on the workplaces.
- The implementation of the object class library as a simulation template in the *ARENA®* simulation environment was described and the parameters available for configuring the characteristics and functionality of the modules of the template as well as their visualization were presented. The way of modeling specific aspects and situations (e.g., the interruption of a task by a task with higher priority, the interactions taking place at the workplace or the way in which the result of a processing requested by an IT worker and carried out somewhere else in the model is processed) was explained.

The described framework provides a conceptual basis and tools for building simulation models of ICT management processes. Using the framework promotes a consistent approach to developing such models and contributes to increasing the effectiveness and efficiency of the modeling process and the comparability, reusability and credibility of the achieved results.

The use of the elements of the framework presented in this chapter is not dependent on the specific practical situation and the approach used to carry out the simulation study. However, using a well-defined simulation approach is of critical importance for the simulation study. Therefore, in the next chapter an approach in the form of a sequence of steps for simulating ICT management processes is presented. The activities that have to be carried out as part of the steps are described and their relationships with the elements of the framework are explained. The way in which the framework and the approach can be applied for building simulation models of ICT management processes is described in chapters 6 and 7, where two simulation cases based on practical situations are presented.

Chapter 5

A Step-by-Step Approach for Simulating ICT Management Processes

5.1 Introduction

In chapter 3 characteristics of ICT management processes relevant to the building of simulation models were identified and requirements with regard to the capabilities and functionality of such models were defined. Based on this, in chapter 4 a conceptual basis and a set of modeling constructs for the building of ICT management simulation models were described. However, before applying the conceptual basis and the modeling constructs for building simulation models based on a practical situation as described in chapters 6 and 7, it was necessary to decide *how* to do that, i.e., to determine the steps that had to be taken in order to build such models in an effective and efficient manner taking into account the defined requirements.

As discussed in chapters 1 and 2, due to the little research in the area of ICT management processes simulation, there is currently a lack of clarity about the exact steps that have to be taken in order to build simulation models of such processes. A basic set of steps that should be followed during a simulation study can be found in most of the simulation approaches reported in the literature (see, e.g., Carson, 1996; Bridgeland and Becker, 1994; Robinson and Bhatia, 1995; Nordgren, 1995; Pegden et al, 1995; Giaglis and Paul, 1996; Hlupic and Robinson, 1998; Law and Kelton, 2000). These steps include the problem definition for the study, the definition of the scope of the study, the collection of the necessary data, as well as the development, verification, validation and use of the simulation model. However, due to the fact that the majority of these approaches have been developed for the purposes of a specific simulation study, there is a great diversity in the content of the steps, the way in which they are carried out and the specific aspects they focus on. As a result of this it is often not clear how these steps can be applied for the purposes of ICT management processes simulation. More specifically, it is not clear how data about the processes under investigation can be collected, how the conceptual model of the processes can be developed, and how the simulation model can be built and used.

Therefore, in this chapter the steps that have to be taken in order to build and use simulation models of ICT management processes are described in the form of a step-by-step approach. In line with this, the goal of the chapter is to:

- Define the steps that have to taken in order to build and use simulation models of ICT management processes, taking into account the defined requirements with regard to the capabilities and functionality of such models.

The application of the step-by-step approach and the framework described in the previous chapter for building simulation models of ICT management processes in a practical situation is described in chapters 6 and 7 of this thesis.

This chapter is organized as follows. In section 5.2 the steps of the approach are presented and a detailed description of each of them is provided. In section 5.3 conclusions are made about the approach and the possibilities it offers, and its use in the next phases of the research is indicated.

5.2 The Steps of the Approach

As mentioned above, a number of simulation approaches have been reported in the literature describing the steps that have to be taken in order to build simulation models for a specific domain of application. Although the basic steps of these approaches are similar, their interpretation in each specific situation depends strongly on the concrete area of application. This leads to a large diversity in the content of the steps. Therefore, it is not immediately clear which (parts of the) steps of the different approaches apply to the area of ICT management processes simulation. There is also a lack of guidelines with regard to the way in which the steps should be carried out and the specific aspects that should be taken into account when simulating ICT management processes.

In order to fill this void a step-by-step approach for simulating ICT management processes was developed as part of this research. The approach is based on steps from other simulation approaches. However, only steps that are relevant to the building of ICT management simulation models have been chosen, and the content of these steps has been adapted and extended in order to reflect the specific aspects of ICT management processes simulation. The steps of the approach are defined as follows:

- Step 1: Problem definition and demarcation of the study
- Step 2: Data collection
- Step 3: Conceptual model development
- Step 4: Building the simulation model
- Step 5: Experimentation and results interpretation

The conceptual framework and the library of object classes described in the previous chapter are used extensively in the steps of the approach. The conceptual framework is used to impose a structure on the data collection carried out in step 2 by defining the elements for which data need to be gathered as well as their basic characteristics. It also provides the basis for the development of the conceptual model carried out in step 3. The library of object classes provides the basis for defining the classes necessary for the development of the conceptual model in step 3 by providing a specification of the basic classes that need to be included in the model and their properties and methods. It also provides the (basic) simulation constructs for the building of the simulation model carried out in step 4. The relations of the conceptual framework and the library of object classes to the steps of the approach are illustrated in fig. 5.1. More details are provided where necessary in the description of the steps.

A detailed description of the steps is given in the following sub-paragraphs. For each step a general explanation of the goal of the step is given and the activities that have to be carried out are described. In this description the emphasis is laid on the specific aspects, which have to be taken into account when simulating ICT management processes and where necessary guidelines are given with regards to how the step should be carried out. Although the way in which the steps are ordered represents the logical sequence in which they should be carried out, in practice they are carried out repetitively and iteratively, depending on the characteristics and the requirements of the specific simulation study.

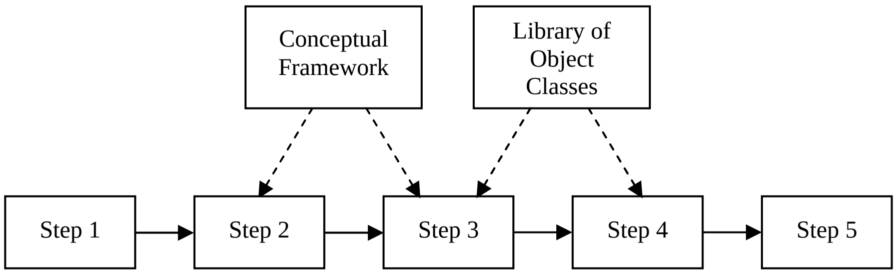

Figure 5.1: The relation of the conceptual framework and the library of object classes to the steps of the approach

5.2.1 Step 1: Problem definition and demarcation of the study

The goal of the first step in a simulation study is to set the scene for carrying out the study by formulating the problems that will be addressed, defining the goals that have to be achieved, and defining the scope of the study. The step encompasses the following activities:

- *Formulate the problems* – in order to achieve a clear description of the problem situation at the onset of a simulation study the exact problems that the study will address need to be formulated. This has to be done in close cooperation with the people responsible for or involved in the problem situation. Depending on the concrete situation, the formulation can have a descriptive form, or be expressed by quantitative means, e.g., by specifying values of key performance indicators for the processes under investigation. A clear problem formulation provides a basis for defining the goals of the study and assessing the achieved results.
- *Define the goals* – the goals* of a simulation study are defined in relation to the problems that are in the focus of the study. The goals describe the concrete results that the study aims to achieve and the questions about the processes under investigation it aims to answer. Depending on the specific situation, the goals may vary from providing insight

* In some simulation studies the term *objective function* is used instead of *goals*. This is the case mostly in situations where the simulation study aims at optimizing (a) certain model parameter(s), often expressed in the form of a mathematical expression. However, in the current research the simulation study in many cases aims at providing insight into the working of the modeled processes and/or the effect a certain change will have on their parameters, rather than at optimizing a certain parameter. Therefore the term *goals* is used throughout this thesis to describe the desired result of a simulation study.

into the processes under investigation, to obtaining information about certain aspects of their behavior, to producing quantitative information about the effect of a proposed change to the processes on the process characteristics. Clearly specified goals are a critical success factor for a simulation study, and play a leading role in the model development and experimentation and in the interpretation and assessment of the achieved results.

- *Specify the scope*– after formulating the problems and defining the goals of the simulation study, the scope of the study has to be defined by choosing the processes that will be in the focus of the study, and describing the restrictions that apply. This is done in close cooperation with the people responsible for or involved in the processes. A common criterion for choosing the processes to be simulated is their relevance to the goals of the study. However, other factors can also play a role here. Examples of such factors are the extent of formalization of the process structure, the possibilities for obtaining enough process data, and the available resources for carrying out the study. As explained in chapters 1 and 2, simulation is most useful for modeling well-structured processes where the differences among the times for carrying out tasks or processing certain objects are relatively small in most cases. Therefore, the processes that render themselves best to simulation techniques are the ones that are closely related to the actual delivery and support of ICT services, and are found mostly at the operational level. An important aspect of the scope of the simulation study is the definition of the restrictions that apply to the study, e.g., the available information, time, budget, and the required detail of modeling. These restrictions should be determined at the onset of the study and taken into account when defining its scope.

5.2.2 Step 2: Data collection

In this step data about the processes under investigation are collected. Due to the fact that the conceptual framework presented in the previous chapter captures the generic structural elements of the processes and their relationships, the data collection performed in this step aims at providing information about the implementation-specific characteristics of the processes (see chapter 3). In line with this, the goal of this step is to obtain a description of the concrete implementation of the generic structural elements, the logic of the processes and quantitative information about the processes.

Having this in mind, we can divide the data that have to be collected in this step into two main types: *structural* and *quantitative*. The *structural data* provide information about the concrete implementation of the generic structural elements and the logic defining their relationships, functionality and the way in which they interact. The *quantitative data* provide empirical information about the stochastic aspects of the processes, e.g., the characteristics of the information objects that form the input and output of the processes, the frequency of arrival of information objects, the delays associated with the processing of the objects by the different components of the process, as well as the frequency of occurrence of certain events in the processes.

The conceptual framework described in the previous chapter should be used in this step to facilitate and impose a structure on the process of data collection. The elements of the framework and their relationships should be used as a basis for gathering structural data about the processes, while their characteristics should be used to determine the types of quantitative data that have to be collected.

Taking into account the two types of data described above, the following two activities should be carried out as part of this step:

- *Gather structural data* – several sources and techniques should be considered when gathering structural data about the processed under investigation. Firstly, a thorough *documentation study* should be carried out. Available documentation about the processes, reports describing process characteristics and performance, work instructions used at the different workplaces, as well as data in electronic form stored in databases used in the processes can be a valuable source of information and should be studied carefully. Due to the rapid (and sometimes even chaotic) developments in the field of ICT, management processes are often set up on an ad-hoc, evolutionary basis without using formal approaches and techniques, and therefore they are very often poorly documented. However, documentation describing the information flows within the process, the different parties and/or persons involved in them and their responsibilities can provide valuable information with regards to the general logic governing the process, its different elements and the people and departments involved in it, which can be used as a basis for the further data collection. Secondly, carrying out *interviews* with managers or people with specific knowledge involved in the processes under investigation is an effective way of obtaining data about the general structure and organization of the processes, as well as about specific process aspects. These interviews can have a formal nature (i.e., have a predefined goal and structure) or be in the form of an informal conversation (e.g., during the coffee break or lunch) with the person in question. Thirdly, *questionnaires* can be used to gather data from people taking part in or having knowledge about the processes. Questionnaires are written sets of questions that are presented to the people involved in the processes under investigation. They provide a well-structured, uniform and relatively unbiased way to gather easy-to-analyze data from a large base of people. Fourthly, *direct observation* of the functioning of the processes can be used to gather information about the tasks and activities carried out as part of the processes, and about the interaction of the different people and departments involved in them. It also offers an effective way of validating the information obtained using the previous three techniques. Fifthly, *direct involvement* in the processes under investigation can be used to gather detailed data and gain first-hand understanding about certain aspects of the processes, which may not be feasible or possible by using the first two methods. The exact use of these techniques depends on the characteristics and requirements of the concrete simulation study, however, the specific possibilities each of them offers allow them to complement each other in order to obtain the data necessary for the building of a simulation model.
- *Gather quantitative data* – next to the structural data, quantitative data need to be gathered about the processes under investigation. This includes data about the frequency of occurrence of certain events in the processes (e.g., breakdowns in equipment) or the arrival of certain information objects (e.g., incidents, questions or requests), as well as data about the duration of tasks and activities carried out as part of the processes. These data are necessary for modeling the quantitative aspects of the processes (e.g., throughput, processing times and workloads) and allow for capturing their dynamic and stochastic nature. The techniques described above can also be used for gathering quantitative data, however, special attention has to be paid to the processing of the data in order to obtain usable and valid data.

5.2.3 Step 3: Conceptual model development

The conceptual model forms the basis for building the simulation model of the processes under investigation. It reflects the way of thinking about and representing these processes and offers a way of translating the simulation requirements into a detailed design framework, from which the simulation model can be built (DMSO, 2000). The main purpose of the conceptual model is to describe the entities that will be included in the simulation model (Fishwick, 1995), their basic characteristics and functionality, as well as their relationships and interactions. It can contain graphical elements (e.g., block diagrams, interaction diagrams and flow charts), as well as elements described in pseudo-code (Pegden et al, 1995). The conceptual model reflects the concept of the simulation developer about the aspects of the processes under investigation which should be captured by the simulation model and the way in which this should be done. It is also an important means of communication between experts in the system under investigation and the simulation developers, and promotes the reuse of the achieved simulation results (Pace, 2002).

Due to the fact that we have chosen an object-oriented approach for building the simulation models, the conceptual model built in this step should include the *classes* that will be used to represent the implemented process elements and their properties and methods. It should also capture the *relationships* of these classes. The conceptual model should contain a *mapping of the process logic* which captures the information exchange taking place as part of the processes under investigation, the rules governing it, as well as the logic governing the work at the individual workplaces. An important aspect of the development of the conceptual model is its *validation* which ensures that the model is a correct representation of the processes and offers enough detail for achieving the goals of the study. In line with this, the following three activities are defined for this step:

- *Identify classes and their relationships* – the purpose of this activity is to identify the classes that will be used for building the simulation model and specify their characteristics, functionality and relationships based on the information about the elements of the processes under investigation gathered in the previous step. The classes of the object class library presented in the previous chapter should be used to represent these elements and specify their characteristics and functionality. In the cases where this cannot be accomplished using the existing classes, new classes should be defined*. A specification of the newly defined classes should be provided where necessary in order to indicate the changed characteristics and functionality of these classes compared to the basic classes of the object class library.

  After identifying the classes that will be used for building the simulation model the relationships among them should be specified. Due to the fact that most of the relationships are already captured in the structure of the library of object classes, the focus here should be laid on specifying the *inheritance* relationships among the newly defined classes and the classes of the library, as well as on specifying the interactions among the identified classes. The interactions among the classes should be captured by building an *interaction diagram* (Fowler and Scott, 1997; Bennett et al, 1999) of the processes under investigation. It should be noted, however, that only classes representing workplaces and

* Due to the fact that the classes *Workplace* and *Equipment* are defined as abstract classes, they will always need to be redefined in order to model the corresponding process elements.

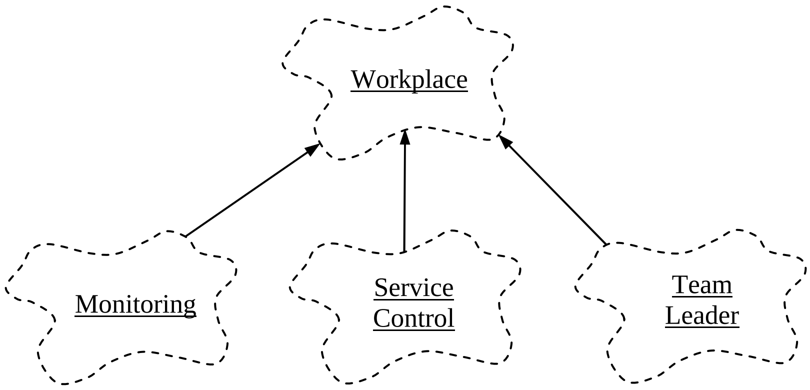

Figure 5.2: The *Workplace* classes of the Incident Management process

equipment should be included in the interaction diagram due to the fact that only such classes can initiate an interaction or respond to one.

In order to provide an illustration of this, we will use the Incident Management process described in chapter 3. Six basic information objects* can be defined as part of the process. These information objects are *Message, Trouble Ticket, Incident Escalation, Standard Solution, Data Request* and *Report*. The characteristics of these information objects can be captured by the corresponding class defined as part of the library and therefore no new classes need to be defined to represent them in the model.

As discussed in chapter 3, three workplaces were involved in the Incident Management process. These were the *Monitoring, Service Control and Team Leader* workplaces. In order to represent these workplaces and capture their characteristics and functionality, three new classes need to be defined. These classes are based on the *Workplace* class defined in the object class library. This is depicted in fig. 5.2. The classes inherit the basic structure of the *Workplace* class and provide a concrete definition of its *Tasks* attribute. The definition of the *Tasks* attribute for each of the classes corresponds exactly to the tasks for the respective workplace defined in chapter 3. Therefore, no further specification of the classes is provided here.

Three kinds of equipment were used in the Incident Management process. These were the *Incident Database*, the *HP ITO Server* and the *WiX Server*. In order to represent them and capture their characteristics and functionality, three new classes need to be defined (one for each kind of equipment). These classes are based on the *Equipment* class defined in the object class library. They inherit the basic structure of this class and add methods representing the logic for processing information objects. This is depicted in fig. 5.3.

* The term *information object* is used here to denote the corresponding process element defined in chapter 4, and should not be confused with the term *object* used to denote an instance of an *object class* in the object-oriented terminology.

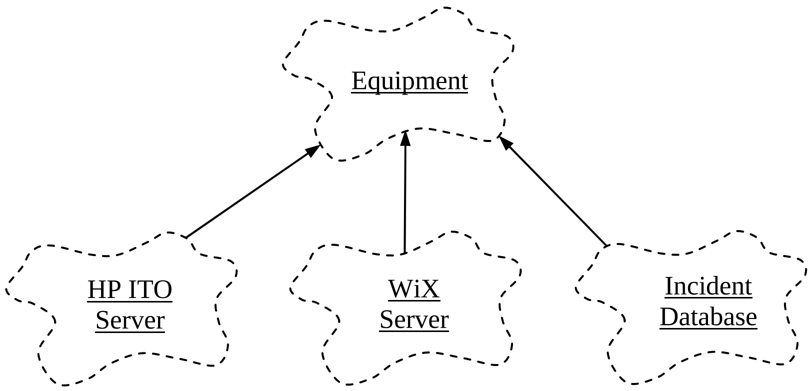

Figure 5.3: The *Equipment* classes of the Incident Management process

The specification of the three classes and the methods added to them are depicted in fig. 5.4. As it can be seen from the figure, a *Process Message* method was added to the *HP ITO Server* class. This method represents the logic necessary for prosessing the incoming messages. A *Process Query* method was added to the *WiX Server* representing the logic necessary for processing the queries for standard solutions. A *Process Incident* and *Process Data Request* methods were added to the *Incident Database* class. The first method represents the logic necessary for processing incoming incidents and dispatching them to the correct workplace or department. The second method represents the logic necessary for processing requests for data about incidents created at the Production Monitoring department.

Object class *HP ITO Server*	**Object class** *WiX Server*	**Object class** *Incident Database*
Inherits from	**Inherits from**	**Inherits from**
Equipment	*Equipment*	*Equipment*
Methods	**Methods**	**Methods**
Process Message ()	*Process Query ()*	*Process Incident ()*
		Process Data Request ()

Figure 5.4: The specification of the three *Equipment* classes

The interactions of the object classes representing the workplaces and equipment of the Incident Management process are captured in the interaction diagram depicted in fig. 5.5. The interactions are based on the description of the process provided in chapter 3. The information objects exchanged in the interactions are not explicitly included in the figure. They are captured in the models of the process logic presented below.

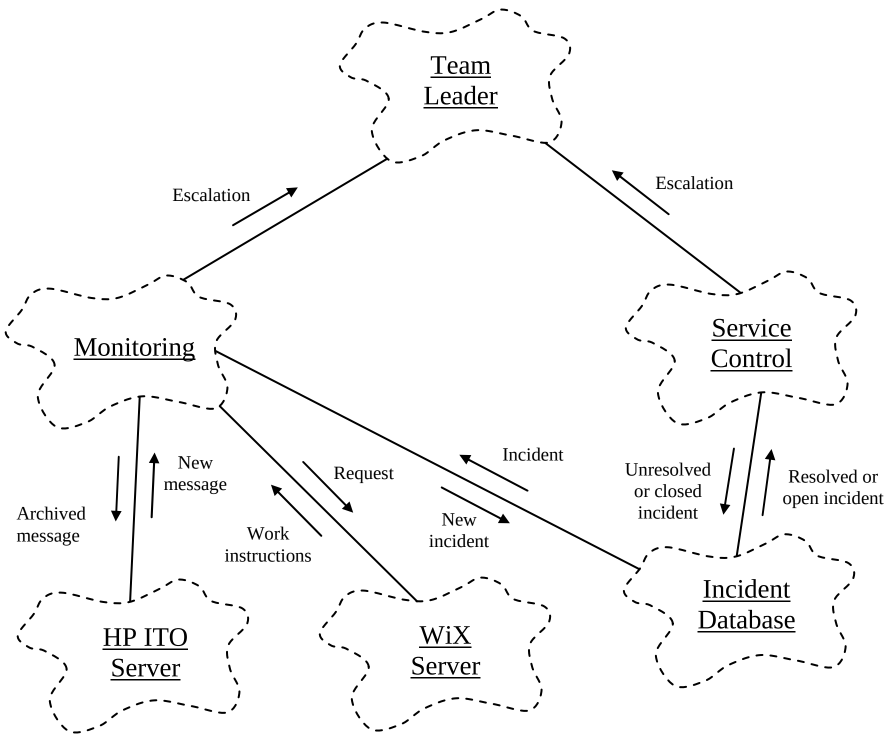

Figure 5.5: The interaction diagram of the Incident Management process

- *Model process logic* – the process logic determines the exchange of information that takes place as part of the processes under investigation and contains the rules governing the functioning of the different components of the processes both on individual and process level. We have chosen three main models to capture this logic. These are the *communication model*, the *process model* and the *workplace model.* These models can be described as follows:

  - *Communication model* – this model captures the exchange of information that takes place as part of the processes under investigation. It comprises of the workplaces and equipment included in the conceptual model and the information objects exchanged as part of their interaction depicted on fig. 5.5. It also includes parties external to the processes, which provide input to or receive output from the processes as well as the information objects exchanged with them. In this way, the model provides an overview of the process components and external parties involved in the communication, reflects the information objects received and/or produced by each of them and their sources and recipients. This forms the basis for building the user view of the simulation model of the processes. An example of a communication model for the Incident Management process described in chapter 3 is depicted on fig. 5.6. The model includes the workplaces and the equipment depicted in fig. 5.5 as well as the *Technical Infrastructure and Applications* that generated the messages processed as part of the process, the *Problem Resolution Departments* resolving the created trouble tickets, the *Client Service* department receiving incident reports about major disturbances and the *Management* receiving reports about the functioning of the process. The arrows connecting the different components of the model reflect the communications that take place, as well as the initiator and the recipient of each communication. Furthermore, information object icons are depicted on each of the arrows indicating the exact information object exchanged during the communication. An explanation of the abbreviations used to denote the names of the information objects is provided in the legend included in the figure.

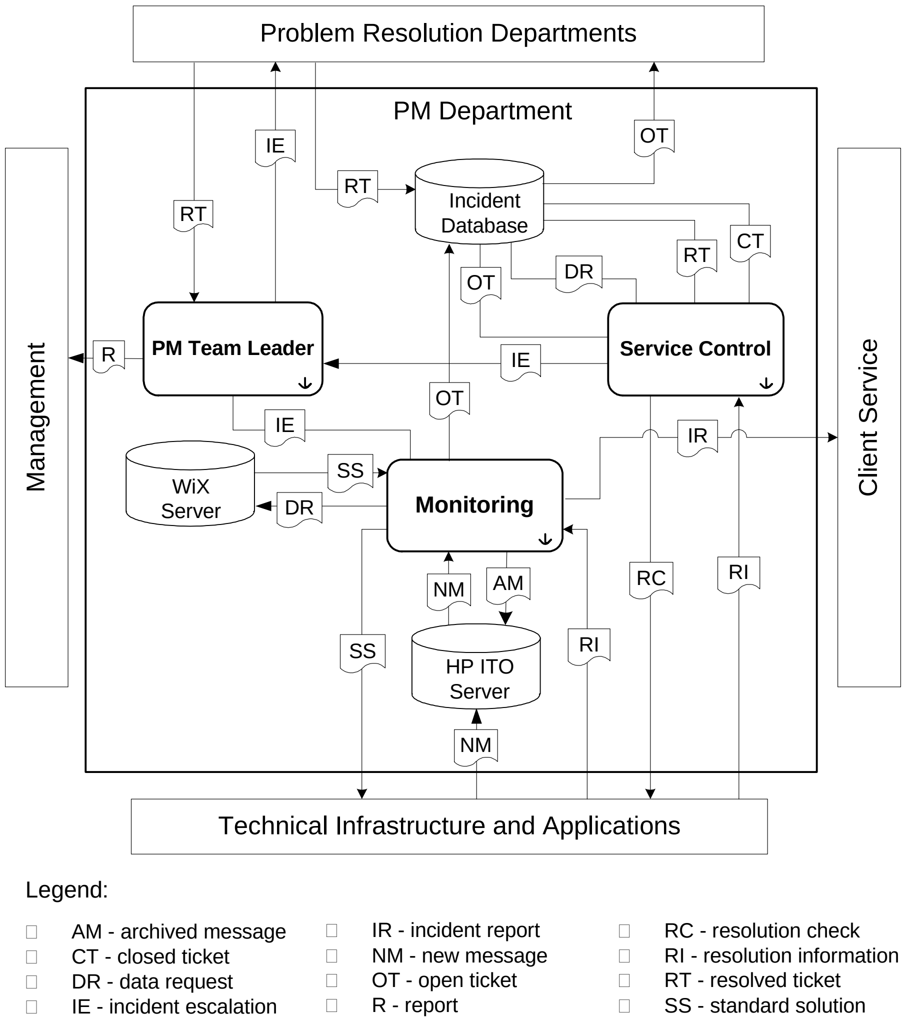

Figure 5.6: The communication model of the Incident Management process

- *Process model* – the process model provides information about the tasks carried out in the processes under investigation, the workplaces at which they are carried out, the order in which they are executed and the conditions which determine that order. The model also includes the external parties which provide input to or receive output from the processes, as well as the information objects serving as an input to or output of a task. Two considerations played an important role when choosing the notation for building the process model. First, the notation had to explicitly represent the tasks carried out at the different workplaces involved in the process(es) under investigation and their constituent activities. Second, the notation had to be intuitive, i.e., easily readable for subject matter experts without requiring them to acquire an additional background in process modeling techniques. A notation that matches closely these requirements is described in (de Vreede, 1995) and (van Eijck, 1996). This notation was used as a basis for the current process model notation. However, two extensions to this notation were made. First, icons representing information objects were included. Second, icons representing parallel execution (the so-called "FORK" primitive in Petri Net terminology) and icons representing the synchronization of information objects necessary for carrying out a certain task (the so-called "JOIN" in Petri Net terminology) were also included. The set of symbols used in the notation is depicted in fig. 5.7. As it can be seen from the figure, the tasks are represented by means of icons, which provide information about the name of the task and the workplace at which it is carried out. The conditions governing the sequence in which the tasks are carried out are represented by a circle denoting the point where a choice has to be made (logical "OR") accompanied by a description of the condition associated with it. The symbols used for the "FORK" and "JOIN" primitives are similar to the ones used in the Petri Nets notation. The external parties are represented by means of an icon surrounded by a dotted line. A distinction is made between simple tasks consisting of one activity and complex tasks consisting of more than one activity and using additional logic to determine the activity that has to be carried out. The latter are represented in the process model by adding the letter "C" in the upper right corner of a task icon. Information objects icons are included to represent the input to or output from the tasks. An example of a process model based on the Incident Management process described in chapter 3 is depicted on fig. 5.8. The abbreviations used to denote the names of the information objects are the same as the ones used in fig. 5.6.

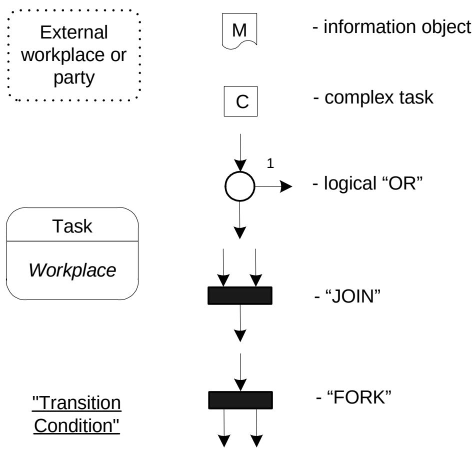

Figure 5.7: The notation for the process model

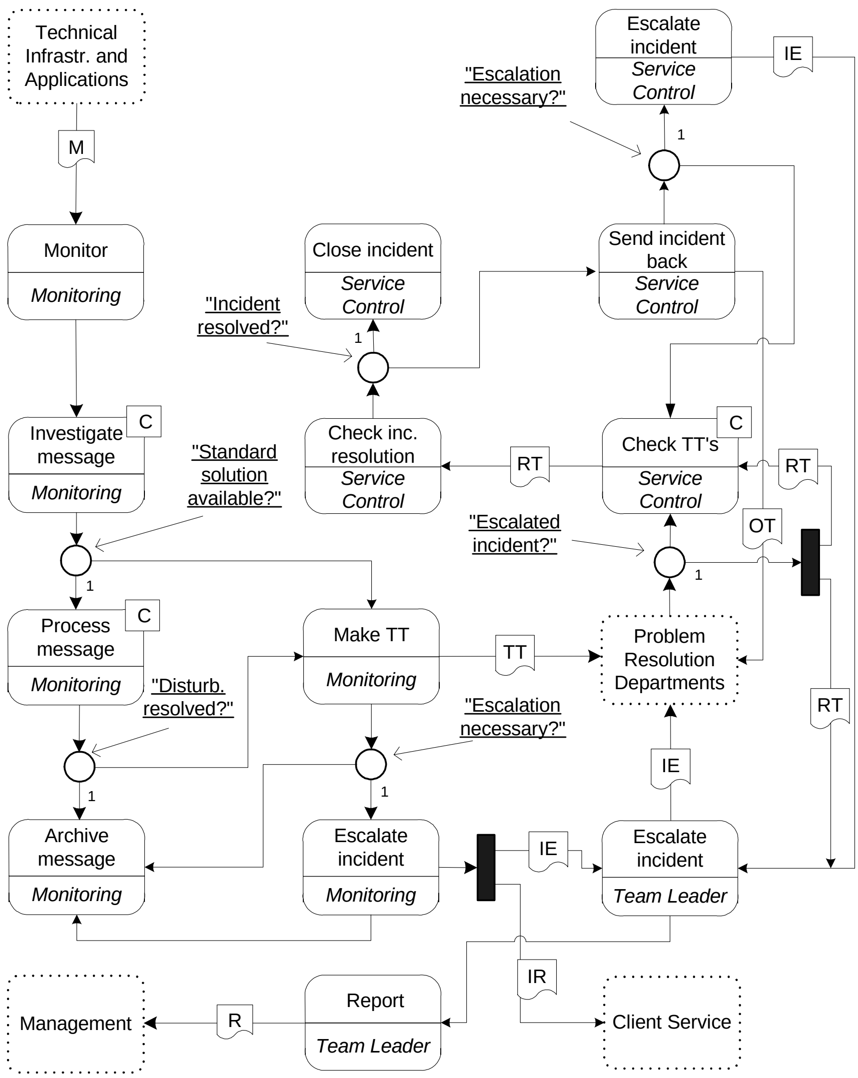

Figure 5.8: The process model of the Incident Management process

- *Workplace model* – the workplace model is based on the so-called “actor model” described in (de Vreede, 1995) and (van Eijck, 1996) and represents the tasks and activities carried out at the workplace and the logic and conditions governing the sequence in which they are carried out. However, instead of providing just a flowchart of the logic followed at the workplace as described in the two sources mentioned above, we have extended this model to incorporate the information objects processed at the workplace and their sources and/or recipients, as well as the used equipment. In this way the model provides a structured representation of the work at the workplace, the rules followed when choosing and processing the information objects, and the workplaces and/or departments sending input or receiving output from the workplace. The notation used to build the model is similar to the one used for the process model. It is depicted in fig. 5.9. As it can be seen from the figure, the activities are represented by icons similar to those used to represent the tasks in the previous model. In case an activity is part of a complex task the name of the task is also included in the icon. Icons surrounded by a dotted line represent workplaces and external parties serving as sources and/or recipients of information objects processed at the workplace. Information object icons are included to represent the input to or output from the activities. An example of a workplace model based on the *Service Control* workplace described in chapter 3 is depicted in fig. 5.10. The abbreviations used to denote the names of the information objects are the same as the ones used in fig. 5.6.

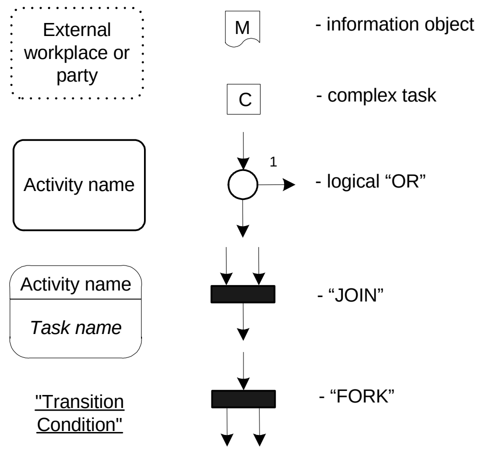

Figure 5.9: The notation for the workplace model

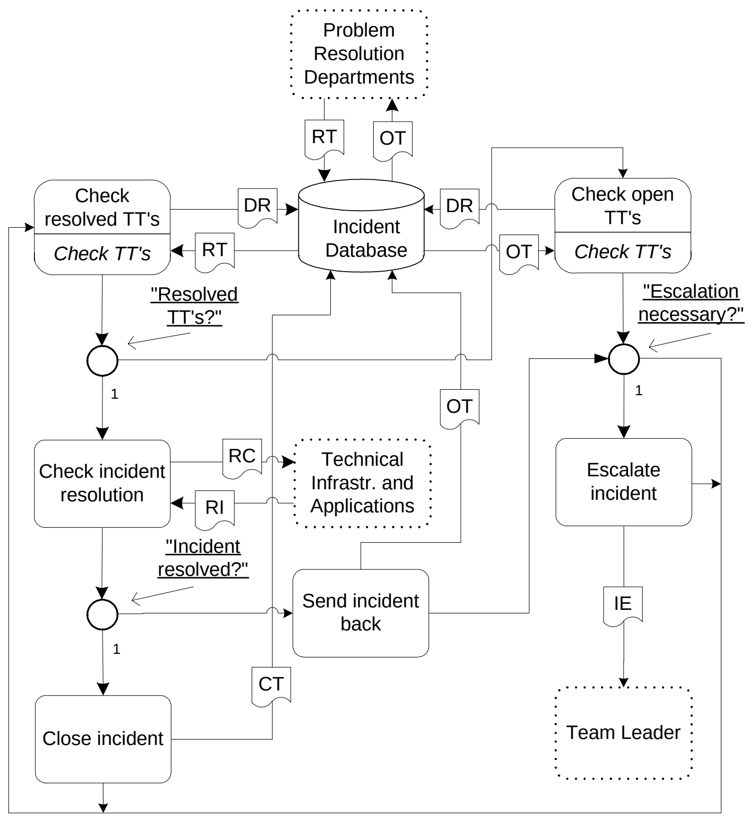

Figure 5.10: The workplace model of the *Service Control* workplace

- *Prepare model data* – the goal of this activity is to transform the raw process data gathered at the previous step in a form suitable for use in a simulation model. This includes the analysis of data about information object arrival frequencies, processing times, transporting delays and frequencies of occurrence of certain events in the processes. Depending on the purposes of the simulation study and the capabilities of the used simulation tools, these data can get the form of a discrete data set (i.e., a finite set of data values that can be used in a simulation model), or a certain stochastic distribution can be fitted to the data, which can later be used in the model in combination with a random number generator. A more detailed discussion on data processing and analysis is outside the scope of this report. More information on the topic as well as examples can be found in, e.g., (Pegden et al, 1995) and (Law and Kelton, 2000).
- *Validate the conceptual model* – the main purpose of the validation of the conceptual model is to ensure that the assumptions made in the model about the processes under investigation correspond to a sufficient extent to the modeled reality. To a sufficient extent meaning that the conceptual model should be a realistic representation of the process structure and functioning taking into account the goals of the simulation study and the restrictions that apply. Care should be taken to maintain a balance with regards to the level of detail included in the conceptual model, so as to make possible the achievement of the goals of the study without increasing unnecessarily the model complexity. In order to validate the conceptual model, all of its constituent parts have to be reviewed in the context of the simulation study. A widely used approach for validating conceptual models is the so-called *subject-matter experts (SME's) review* (Law and Kelton, 2000; DMSO, 2001a). This approach is based on involving people closely familiar with (parts of) the processes under investigation in reviewing (parts of) the conceptual model. The review can be in the form of submitting individual comments on a printed form of the model, or a group review including a presentation of the developed model and a brainstorming session with the participation of several SME's. The SME's review is a particularly useful approach in the field of ICT management processes simulation. This is due to the fact that, because of the rapid developments in the area of ICT, the processes have evolved and taken shape with time rather than being carefully engineered at the beginning, and much of the process knowledge is not formally recorded in the available documentation. The knowledge of the SME's should therefore be used to validate the assumptions about the structure of the modeled processes and their logic, as well as the obtained quantitative data and the applied stochastic distributions. The validation of the conceptual model can help to determine the fitness of the representation of the different components with regards to the purposes of the simulation study, and for identifying and correcting problems and errors in an early stage in the simulation project. A valid conceptual model forms a sound basis for the subsequent designing and building of the simulation model.

5.2.4 Step 4: Build the simulation model

In this step the simulation model of the processes under investigation is built based on the gathered structural and quantitative data and the developed conceptual model. The building of the model includes the formulation of the model structure and logic in an appropriate simulation language, filling in the collected data, and the verification and validation of the model. An important part of this step is also the development of the graphical representation of the model and the decision what information should be interactively displayed on the screen during the simulation runs. In line with this, the following activities are defined for this step:

- *Build model structure and logic* – this activity aims at implementing and visualizing the functional components of the processes under investigation and their interactions. Based on the developed conceptual object model(s), the structure of the simulation model is built by using the components of the object class library for ICT management simulation described in chapter 4. The attributes of the implemented objects are adjusted so as to reflect the specific characteristics of the different process components. The logic followed at the different workplaces of the model, as well as the logic governing the inter-process information flow are implemented. Performance indicators for the processes are added to the model in the form of equations based on certain model parameters. Any additional model components (e.g., random event generators, blocks for calculating and recording the value of performance indicators or components reading or writing to data files) necessary for the functioning of the model are included. The graphical representation of the model is built and the animation of certain components (e.g., the information objects or certain types of equipment) is adjusted so as to provide a clear and understandable visualization of the work of the model. Components providing interactive visualization of the values of certain model parameters and performance indicators are also added to the graphical representation.

- *Fill in the model data* – the collected data about the processes under investigation are entered into the model. This includes data about frequency of arrival of information objects, frequency of occurrence of certain events in the model, processing times at the workplaces and the different pieces of equipment, and the delays associated with transporting the information objects among the different process components. An important decision that has to be made at this stage concerns the correspondence between real-world and model time units, i.e., whether one model time unit corresponds to one second, minute, hour, etc. in the real processes. Furthermore, a distinction has to be made between data that have a constant character and data that have stochastic character. In the latter case the data have to be entered using an appropriate stochastic distribution or as a set (file) of discrete values, as mentioned above. When all the necessary data are entered, the model is ready for verification and validation, which are described in the next paragraphs.

- *Verify the model* – the purpose of model verification is to ensure that the model functions correctly and as intended. This is done by trying to find and eliminate errors in the logic and the computer representation (coding) of the model. Therefore, verification is also often called “debugging” of the model (Pegden et al, 1995; Law and Kelton, 2000). Different techniques are available for verifying simulation models. Among the most widely used are structured walkthrough of the model logic, observation of certain parameters of the model like the generated stochastic data or the time a certain resource is busy, performing test runs using special test data and modeling conditions, and tracing model operation. The use of animation can greatly assist the process of model verification by, for example, visualizing the functioning of certain model components, enabling the interactive observation of model parameters, and showing the places in the model where information objects are created, processed and sent to. A more detailed discussion on model verification and the available techniques is provided in, e.g., (Pegden et al, 1995), (Law and Kelton, 2000), (Balci, 1998) and (DMSO, 2001b). The verification of the simulation model ensures that the model is implemented correctly and uses the right data at the right place and at the right time.

- *Validate the model* – The purpose of model validation is to ensure that the simulation model is an accurate representation of the processes under investigation. This has to be substantiated taking into account the domain of application of the model and the specific goals of the simulation study (Balci, 1997; Law and Kelton, 2000). Many validation methodologies and techniques have been developed and reported in the literature depending on the type of simulation used and on the available information about the modeled real system(s). Detailed reviews of these methodologies and techniques are provided in, e.g., (Pegden et al, 1995), (Law and Kelton, 2000), (Balci, 1998) and (DMSO, 2001b). The following four techniques can be successfully applied for validating simulation models of ICT management processes. *Face validation* is a widely used technique according to which SME's and other people involved in the processes under investigation review the output of the simulation model in the form of model parameters, performance indicators of the processes, input and output data and animation of the model operation. In order for the model to be valid, the generated output should be characteristic of the real-life processes. *Testing of parameters and relationships* is a technique, which includes the testing of the underlying assumptions about certain parameters in the model and their relationships with other parameters or variables by varying the values of these parameters and comparing the obtained results with the expected values. *Behavior comparison* is another popular validation technique. It consists of comparing the behavior of the simulation model with the behavior of the processes under investigation by measuring a certain set of model parameters and applying statistical tests (e.g., Chi-Square test, Kolmogorov-Smirnov test, Regression analysis, Spectral analysis, etc.) to determine the difference between the model-generated values of these parameters and their real-life equivalents. Different *statistical techniques* (Kleijnen, 1999) can also be applied depending on the availability of real data about the processes under investigation. Which of these techniques will be applied in a concrete simulation study depends on a number of factors, among which the type of the simulated processes, the goals of the simulation study, the available data and the constraints that apply with regards to time, tools, budget, etc. However, the validation of the simulation model is of critical importance for the credibility of the model and for building confidence in the simulation results obtained from its use, and therefore should receive enough attention in a simulation study.

5.2.5 Step 5: Experimentation and results interpretation

The last step in a simulation study is the carrying out of simulation experiments in order to gather information about the processes under investigation. The information gathered during the experiments is subsequently analyzed and interpreted in the context of the goals of the simulation study in order to draw conclusions about certain process characteristics, estimate the expected impact of a change to the processes, or choose among alternative process structures. In line with this, the following two activities are defined for this step:

- *Test alternative scenario's* – the developed simulation model is used to test different simulation scenarios for the processes under investigation. A simulation scenario is a predefined set of simulation conditions and usually incorporates changes in different aspects of the simulation model. These changes can include changing the characteristics of the input and/or output information objects and their frequencies of arrival, varying the processing times at different places in the model, changing the structure of the modeled processes by adding or removing workplaces or ICT workers, changing the process logic governing the information flow within the processes or changing the processing logic at the different workplaces in the model. With each scenario one or more simulation runs are carried out in order to obtain output that is statistically valid, and a set of predefined output parameters are recorded. These output parameters can comprise the implemented performance indicators for the processes under investigation, the values of certain model parameters like queue length and resource use, or the characteristics of the output information objects produced by the model. The recorded parameter values can be obtained both from data generated at the end of a simulation run, as well as from data generated interactively during the work of the model and characterizing the dynamic behavior of its elements. The data obtained at this stage serve as a basis for the subsequent analysis and interpretation of the model results.

- *Analyze and interpret results* – the data generated from the experiments with the different simulation scenarios are analyzed and interpreted in order to answer the questions and achieved the goals defined at the onset of the simulation study. Analysis of the data is carried out in order to determine their correctness and usability. Different statistical techniques can be used to determine the degree of independence of the data and obtain estimates of the mean values and confidence intervals of the parameters of interest. Various plots and histograms can also be used to obtain a graphical representation of the values of these parameters and their change over time. A detailed discussion on output data analysis can be found in, e.g., (Pegden et al, 1995) and (Law and Kelton, 2000). After the output data are analyzed, they are interpreted in the context of the defined goals of the simulation study taking into account the restrictions that apply and the used model reductions. In this way informed conclusions can be drawn about the processes under investigation. These conclusions can be related to gaining insight into certain process characteristics, estimating the impact of a change to the processes, or choosing among alternative process organizations.

5.3 Summary

In this chapter a step-by-step approach for the simulation of ICT management processes was presented in the form of a sequence of steps for the building and using of simulation models of such processes. The need for such an approach was discussed and the steps of the approach and their constituent activities were described. The main characteristics of the approach can be summarized as follows:

- The approach consists of a sequence of steps that have to be taken in order to build and use a simulation model of ICT management processes in an effective and efficient manner.
- The goal of each step was described, as well as the activities that have to be carried out as part of the step. The content of these activities, the way in which they have to be carried out and their results were also described.
- In the description of the tasks and their constituent activities emphasis was laid on aspects specific to the simulation of ICT management processes and guidelines were provided with regards to the use of the conceptual framework and the object class library described in chapter 4 of this thesis.
- The steps of the approach were presented in the logical sequence in which they should be carried out. However, in practice the result of a certain step or activity may create the

need to carry out a certain step or activity again. Therefore, the steps and their constituent activities may be carried out in an iterative rather than sequential manner.

The application of the described approach for the simulation of ICT management processes together with the elements of the framework described in chapter 4 for building ICT management simulation models is described in the next two chapters, where two test cases based on practical situations are presented.

Chapter 6

Simulating ICT Management Processes: Test Case A

6.1 Introduction

In chapter 4 a framework for the simulation of ICT management processes was presented. The framework included a set of concepts for building conceptual models, and an object class library for building simulation models of such processes. In chapter 5 an approach was presented which described the steps that have to be carried out in order to build ICT management simulation models, and provided guidelines for using the elements of the framework.

In this chapter and the following chapter 7 the application of the framework and the approach for ICT management processes simulation is presented based on two test cases carried out at the ICT departments of two large organizations* in The Netherlands. The goal of the chapters is to describe the way in which the framework and the approach for simulating ICT management processes can be applied in practice and to validate the ideas, techniques and elements presented as part of them.

This chapter is structured as follows. In section 6.2 the selection, objectives and the methodology of the test cases are described. In section 6.3 a description is provided of the first test case in line with the steps of the approach for simulating ICT management processes presented in chapter 5. In section 6.4 conclusions about the results of the test case and the application of the framework and the approach for simulating ICT management processes are presented.

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* The organizations in which the test cases were carried out prefer not to be mentioned by name and are referred to as *Case A* and *Case B* instead. The names of the departments involved in this case were changed so as to reflect their function only.

6.2 Objective and selection of the test cases

Two aspects played a role in the preparation of the test cases: the objectives of the cases and the selection of the organizations in which they were carried out. These aspects are discussed in the following sections.

Objective of the test cases

The main objective of the test cases was to validate the developed framework and approach for simulating ICT management processes by applying them in a real-world situation. Taking into account the elements, presented as part of the framework, the cases focused on the following aspects:

- *Conceptual model development* – the development of the conceptual model (step 3 of the approach) comprised the identification of the basic elements of the processes under investigation that had to be represented in the simulation model and the specification of their characteristics based on the conceptual framework described in chapter 4. It also included the modeling of the process logic using the communication model, process model and workplace model described in chapter 5, as well as the validation of the conceptual model.
- *Simulation model development* – the development of the simulation model (step 4 of the approach) included the building of the model structure based on the developed conceptual model and using the simulation constructs of the library of object classes for simulating ICT management processes described in chapter 4, as well as the validation of the model.

Selection of the test cases

In order to validate the framework and approach for simulating ICT management processes proposed in this research, organizations had to be found which were willing to participate in the test cases and provide the information necessary to build a simulation model of the ICT management processes implemented there. The selection of these organizations was based on the following criteria:

- *Size of the ICT department of the organization* – the size of the ICT department has a direct influence on the structure and complexity of the implemented ICT management processes. Smaller (up to approximately 50 people) ICT departments tend to work in a more ad-hoc, procedure-oriented manner, and the ICT management is easier to organize and oversee. A larger ICT department, on the other hand, poses bigger challenges with regards to the communication among the different parts of the department and the coordination of the work. This in its turn justifies the implementation and use of ICT management processes for increasing the effectiveness and efficiency of the work. Although we could not find research reports which presented formal evidence on the relation between the size of the ICT department and its perceived complexity, conversations and interviews with ICT managers as well as publications on setting up and implementing ICT management processes in organizations showed that ICT departments with approximately 300 employees and more were considered complex and efforts were made to define and implement ICT management processes. Therefore, a size of 300 employees or more of the ICT department was used as a general guideline in choosing the organizations for the test cases.

- *Type of the implemented ICT management processes* – the type of the implemented ICT management processes also played a role in selecting the organizations for the test cases. As discussed in chapter 1, operational-level processes render themselves better to formalization and modeling by means of simulation, therefore organizations where such processes were implemented were chosen for the test cases. The extent to which these processes were formally defined and the available data also played a role here.

A description of the first test case is provided in the next section based on the step-by-step approach described in chapter 5.

6.3 Case A: A Financial Services Organization

The first test case was carried out in the Operations Management department of a financial services organization in The Netherlands. This department provided ICT services related to the management and security of the applications and technical infrastructure. The department was divided into five sub-departments: Application Management, Technical Management, Technical Implementation, ICT Help Desk and Security. *Application Management* was responsible for the installation, management and troubleshooting of the centralized and decentralized applications. *Technical Management* was responsible for the installation, management and troubleshooting of the ICT technical infrastructure (servers, middleware and operating systems). *Technical Implementation* was responsible for the installation and management of the physical workplaces within the organization. The *ICT Help Desk* was responsible for providing a central contact point for end-users with regard to all questions, incidents and requests related to the ICT infrastructure and applications. Finally, *Security* was responsible for managing and maintaining the security of the ICT infrastructure and applications.

The structure of the Operations Management department is depicted on fig. 6.1.

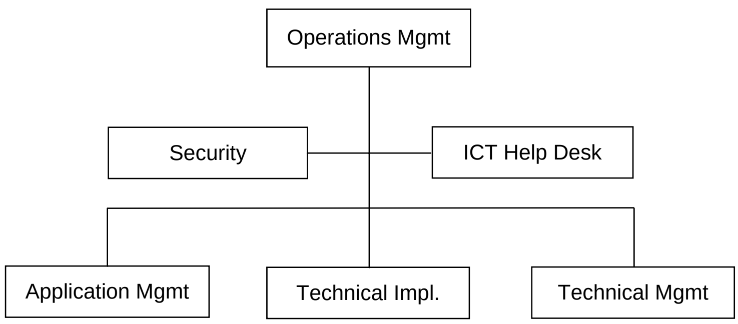

Figure 6.1: The structure of the Operations Management department

6.3.1 Step 1: Problem definition and demarcation of the study

The following sections provide information about the focus of the test case, the problem definition, the goals of the test case and the scope of the case.

Focus of the test case

The test case focused on the ICT Help Desk within the Operations Management department. This choice was based on the fact that, on the one hand, the work carried out at the Help Desk was relatively well-structured and suitable for representation in a simulation model, and, on the other hand, insight into and information about the functioning of the Help Desk were necessary because of a planned reorganization.

The ICT Help Desk served as a central contact point for all incidents, problems and questions related to the ICT services and infrastructure within the organization. The clients reached the ICT Help Desk in two ways – directly by telephone, e-mail or fax, or through client help desks, which offered first-line support for specific departments.

The main task of the ICT Help Desk was to register the clients' calls, provide first-line support, initiate and supervise the second- and third-line incident resolution process, inform the clients when an incident is solved and receive feedback on the quality of the resolution. The registration of the client calls, the first-line support and the initiation of the second- and third-line incident resolution were carried out by the so-called *Front Office* of the ICT Help Desk. The second- and third-line incident resolution was carried out by a number of solution groups, which were generally referred to as *support departments.* The supervision of the incident resolution, the contact with the client and the receiving of feedback were carried out by the so-called *Back Office* within the ICT Help Desk department.

Problem definition

In the course of the work of the ICT Help Desk a number of issues were identified, which needed to be resolved in order to improve the overall quality of incident resolution. These issues were mainly related to the time necessary to resolve an incident and the feedback provided to the client, the unclear division of tasks and the insufficient cooperation and coordination between the ICT Help Desk and the supporting departments. Next to this, a reorganization of the Back Office was planned in order to increase the flexibility and capacity of the Front Office and reduce the waiting time for incoming calls. However, although it was expected that this reorganization would reduce the waiting time and make the handling of incoming calls more flexible, there was a lack of clarity about the exact impact it would have on the work of the ICT Help Desk and on the speed and quality of the overall incident resolution process.

Having this in mind, the problems addressed in the test case were defined as follows:

- Lack of clarity about the division of tasks and responsibilities between the ICT Help Desk and the supporting departments in the process of problem resolution and the way in which they are coordinated.

- Lack of clarity about the impact of the expected reorganization of the Back Office on the work of the Front and the Back Office, the change in workload, as well as the expected changes in the quality of the incident resolution.

Goals of the test case

In relation to the problems addressed by the test case, the goals of the case were formulated as follows:

- Provide insight into the way in which incidents are resolved by modelling the functioning of the ICT Help Desk and its interaction with the clients and client Help Desks on the one hand, and the support departments on the other;
- Model the tasks carried out at the Front and Back Office and the communication and coordination with the departments involved in the incident resolution process in order to identify bottlenecks in the process;
- Based on data about the current incident frequency and the time for their resolution, produce quantitative data about the expected impact of the planned reorganization of the Back Office on the workload of the Front- and Back Office, as well as on the time and quality of the incident resolution.

Scope of the test case

The test case was focused on the tasks carried out at the Front and Back Office of the ICT Help Desk department. It also encompassed the interface of the ICT Help Desk with its clients, on the one hand, and with the departments taking part in the incident resolution, on the other. As explained below, there were two main ways for the clients to reach the ICT Help Desk – either directly by means of telephone, e-mail and fax, or through separate client Help Desks that were set up for certain departments. However, for the purposes of the test case, both the clients directly contacting the ICT Help Desk as well as the client Help Desks contacting the ICT Help Desk with regards to ICT incidents were considered as clients of the ICT Help Desk and will be referred to in this way in the rest of this discussion. Similarly, the different departments taking part in the incident resolution process were considered and will be referred to as support departments.

Due to the fact that more than 98% of all clients contacted the ICT Help Desk by telephone the test case focused on the handling of incoming client calls. The handling of client e-mails or faxes was left out of consideration.

Next to the ICT-related incidents reported by the employees of the organization, the ICT Help Desk served as a central point for receiving requests with regards to new functionality, infrastructure or applications, as well as for requests for moving existing workplaces or setting up new ones. First- and second-line support with regards to incidents related to the Tivoli platform used within the organization were also carried out there. However, these activities were not considered “core” activities of the ICT Help Desk and were left out of consideration throughout the case, taking into account only the influence they had on the workload of the people working at the ICT Help Desk and on the time for answering and handling the incoming client calls.

There were four main places, where data with regards to the incoming calls and their handling were recorded – the Lucent computer telephony system used at the ICT Help Desk and the three database systems used for the registering of the incoming calls, the created incidents and their resolution. The data available and recorded there was considered representative and sufficient for achieving the purposes of the case. Therefore the data used for building and validating the simulation model were restricted to the data obtained from these systems.

The case was focused on the tasks carried out by the people at the operational level, i.e., the registration and handling of calls and incidents, and the subsequent check of the incident resolution and the contact with the client. Management activities related to the work of the ICT Help Desk were left out of consideration and only the effect they had on the performance of the ICT Help Desk was taken into account, except for the cases where the modelling of these activities was necessary for capturing and representing specific situations, e.g., escalation of an incident or problem.

Data about activities not directly related to the core activities of the ICT Help Desk (e.g., vacation, sickness, meetings, coffee breaks, etc.) were used in the model based on assumptions about the average time spent by the personnel of the department on such activities and their frequency.

6.3.2 Step 2: Data collection

In this sub-section the data gathered during the test case and used for building the simulation model of the ICT Help Desk are presented. In line with the approach described in chapter 5, a distinction is made between two different kinds of data: *structural process data* described in sub-section 6.3.2.1 and *quantitative process data* described in sub-section 6.3.2.2.

6.3.2.1 Structural Process Data

The structural data comprise information about the concrete implementation of the generic structural elements described in chapter 3. In line with this, in the next sections information is provided about the *information objects*, the *workplaces, tasks and activities* and the *equipment* used in the work of the ICT Help Desk.

Information objects

Six basic information objects were identified: These were the *Client Call, Incident, Incident Escalation, Standard Solution, Solution Check* and *Solution Information.* A description of these information objects and their characteristics is given below.

The information object *Client Call* represented the client calls arriving at the ICT Help Desk. It was characterized by its *priority* and by the *disturbance* it referred to. The *priority* of the call indicated the speed with which the call had to be processed. The *disturbance* indicated the type of disturbance the call referred to. More information on the different types of disturbances is provided in sub-section 6.3.2.2.

The information object *Incident* represented the incidents created or handled at the ICT Help Desk. It was characterized by its *priority,* the *disturbance* it referred to and its *status*. The role of the first two attributes was similar to the role of the corresponding attributes of the *Client Call* information object. The *status* represented the state of the incident and took the values *client, open, resolved, unresolved* and *closed.* The value *client* represented an incident coming from a client Help Desk. The value *open* represented an incident sent by the Help Desk to the supporting departments for resolution. The value *resolved* represented a resolved incident sent back to the ICT Help Desk by the supporting departments. The value *unresolved* represented an incident sent by the ICT Help Desk back to the supporting departments for further resolution. The value *closed* represented a closed incident.

The information object *Incident Escalation* represented the information exchanged during the escalation of incidents in the ICT Help Desk. It was characterized by the *identifier* of the escalated incident and the *escalation type* which indicated whether the escalation was related to a high-priority disturbance or to an exceeded incident resolution period.

The information object *Standard Solution* represented the solution offered to the client for resolving a known disturbance. The main characteristic of this object was the *disturbance* it was meant to resolve.

The information object *Solution Check* represented the check carried out by an employee of the Back Office of the ICT Help Desk in order to determine whether an incident was resolved according to the predefined quality requirements. The main characteristic of this object was the *disturbance* it referred to.

The information object *Solution Information* represented the information given by a client to an employee of the ICT Help Desk about the resolution of a disturbance. The main characteristic of this object was whether the resolution was *successful* or not.

Workplaces, Tasks and Activities

Four types of workplaces were distinguished within the ICT Help Desk. These were the *Front Office Call Agent, Front Office Client Queue Agent, Back Office Agent* and *Team Leader*. These workplaces, the tasks carried out there and their constituent activities are described in the following sections.

Front Office Call Agent

As explained above, the *Front Office Call Agent* was responsible for receiving the phone calls of the clients of the ICT Help Desk, registering them, performing an initial diagnosis of the reported disturbance, and taking appropriate actions so that it could be resolved according to the predefined time and quality requirements. These actions included checking for a standard solution and offering it to the client, making an incident in case there was no standard solution available or it did not solve the disturbance, and escalating the incident in case of a priority zero disturbance. In relation to this, the tasks carried out by the *Front Office Call Agent* and their constituent activities were defined as follows:

- *Take call* – this task comprised the answering and registration of the phone calls of the ICT Help Desk clients. It consisted of the following activities:
  - *Answer call* – consisted of answering the client call and verifying that the ICT Help Desk is the appropriate department for handling the call. If that was true, the agent

proceeded with registering the call, otherwise he/she rejected the call or redirected it to another department if possible.

- *Register call* – consisted of entering data about the call into the call database of the department. These data included the timestamp of the call, name, address and telephone number of the person calling, description of the disturbance, and affected the hardware and/or software items.

- *Handle call* – in this task initial diagnosis of the reported disturbance was performed and in case a standard solution was available, it was offered to the client. It consisted of the following activities:
  - *Diagnose call* – this activity consisted of determining the cause and making an estimation of the impact of the disturbance based on the information provided by the client. The diagnosis made was then entered into the record for the call in the call database.
  - *Check for standard solution* – after the initial diagnosis of the disturbance, a check was made whether a standard solution was available. The standard solution was defined as a predefined sequence of steps that can be carried out by the agent or the client in order to resolve the disturbance. The available standard solutions were recorded into a special database, which can be searched using different criteria, e.g., symptoms, affected application or system, or hardware item.
  - *Apply standard solution* – this activity comprised the actions carried out by the agent in order to apply (or let the client apply) a standard solution. These actions often included changing the configuration of the affected system/PC or application, restarting the system and backing up and/or restoring user data. After a standard solution was applied the agent verified whether the disturbance was actually solved or further action needed to be taken for its resolution.

- *Create incident* – this task comprised the actions carried out in case there was no standard solution available or it did not solve the disturbance. It consisted of opening a new incident in the incident database and filling in the details about the disturbance, the initial diagnosis performed by the agent and the priority of the incident. After an incident was created it was assigned to a support department, which took care of its further resolution.

- *Escalate incident* – this task was carried out in case of a priority-zero incident. It consisted of informing the team leader of the ICT Help Desk about the incident and collecting and sending the information necessary to determine the exact impact of the disturbance and the affected applications, systems and user groups.

- *Close call* – the last task of the Front Office Call Agent consisted of entering information into the call database about the way in which the call was handled, the applied standard solution or the number of the created incident, after which the call was closed and stored in the database for future reference.

Front Office Client Queue Agent

The *Front Office Client Queue Agent* was responsible for handling the incidents coming from client Help Desks and placed in the so-called "*Client Queue*". As mentioned above, the way these incidents were handled was similar to the way calls were handled, however, in this case an incident was already created by the client Help Desk containing all relevant data. Therefore, the tasks of the *Client Queue Agent* comprised of performing an initial diagnosis of the disturbance reported in the incident, checking if a standard solution was available and applying it, or sending the incident to the appropriate support department for further resolution otherwise. The following four tasks were defined for the *Client Queue Agent*: *Handle Incident, Send Incident, Escalate Incident* and *Close Incident.* The content of these tasks was similar to the corresponding tasks and/or activities of the *Front Office Call Agent*, therefore they will not be specified in greater detail.

Back Office Agent

The *Back Office Agent* was responsible for monitoring the resolution of the incidents assigned to the support departments and for ensuring that this resolution was carried out within the predefined time and quality constraints. This included checking the progress of the resolution of the open incidents and escalating the incident in case the predefined period for resolving the incident had elapsed, as well as checking the quality of resolved incidents and, if necessary, verifying the solution by calling the client who reported the disturbance. In relation to this, the tasks of the *Back Office Agent* were defined as follows:

- *Check open incidents* – consisted of checking on a regular basis the progress of the open incidents assigned to the different support departments and determining whether the time for resolving the incident had been exceeded based on the priority of the incident. If the time had been exceeded the agent tried to determine the reason for the delay, or escalated the incident by informing the team leader of the Help Desk.
- *Check incident resolution* – consisted of checking the quality of the resolution of a solved incident and sending the incident back in case the quality did not meet the predefined criteria. There were two main ways to do this – checking system parameters and calling the client to verify the quality of the resolution. In relation to this, this tasks comprised of the following two activities:
  - *Check system parameters* – included the checking of memory, hard disks, network, database availability and other parameters affected (or part of) the disturbance reported by the user. The check was performed mostly remote, using system management tools available at the Help Desk.
  - *Call client* – included making a phone call to the client to inform him that the incident had been resolved and to ask him to verify the quality of the resolution. The information obtained from the client was then added to the description of the incident resolution.
- *Send back incident* – in case the quality of the incident resolution did not meet the predefined quality criteria, information about this was entered into the incident and it was sent back to the support department for further resolution.
- *Escalate incident* – this task was carried out in case the time for resolving a (high-priority) incident was exceeded. It consisted of informing the team leader of the Help

Desk about the disturbance, the priority of the incident, the amount of time by which the period for resolving the incident was exceeded, and the responsible support department.

- *Close incident* – if the incident resolution met the predefined quality criteria, information about the way in which the resolution was checked was recorded in the incident, and it was closed and saved in the incident database for future reference.

Team Leader ICT Help Desk

The *Team Leader* was responsible for managing the work of the ICT Help Desk. This included the coordination of the tasks and activities carried out at the department, the allocation of human, financial and technical resources, and ensuring that the work of the department meets the predefined service levels. As mentioned above, an important part of the work of the *Team Leader* was the escalation of priority-one incidents or incidents for which the resolution time had been exceeded. The *Team Leader* also provided advice to different departments within IT Production with regards to the way in which reported disturbances in the work of specific applications or infrastructure components were handled by the Help Desk, the information gathered and the further resolution of the incidents by the appropriate support department(s). Attending meetings with clients of the Help Desk and/or support departments, as well as reporting on the performance of the Help Desk were also part of responsibilities of the *Team Leader*. In connection to this, the tasks of the *Team Leader* of the ICT Help Desk were defined as follows:

- *Coordinate Help Desk tasks*– consisted of coordinating the tasks carried out at the ICT Help Desk. This included the distribution of the tasks among the people carrying them out, prioritizing the work, imposing constraints and defining performance parameters based on the agreed service levels.
- *Allocate resources* – consisted of distributing the available people and equipment at the department over the workplaces described above, and reallocating resources (e.g., asking some of the Back Office Agents and/or the Front Office Client Queue Agent to carry out Front Office Call Agent tasks) in case of priority-one incidents or absence of people.
- *Monitor performance* – consisted of reviewing the data about the defined performance indicators of the department (e.g., average waiting time for incoming calls, time for servicing a call and the percentage of calls solved by using a standard solution), comparing these data with the levels defined in the service level agreements for the department, and taking corrective action in case the actual service levels did not meet the predefined levels.
- *Escalate incidents* – consisted of taking actions to ensure the timely resolution of priority-zero incidents. This included informing higher management and the appropriate supporting departments about the incident, informing users about the disturbance, its consequences and the expected resolution time, as well as taking part in the coordination of the incident resolution.
- *Provide advice* – consisted of providing advice to clients, managers and technical specialists with regards to the way in which disturbances reported by clients were handled by the Help Desk, the information gathered in case an incident had to be created, the communication and coordination with the support departments during the incident resolution, as well as the way in which the quality of the resolution was verified.

- *Attend meetings* – consisted of taking part in meetings with regards to the resolution of incidents and problems, coordination with the supporting departments as well as arranging the Help Desk support for new applications and/or infrastructure components.
- *Report on performance* – consisted of providing information to the management about the work of the ICT Help Desk, the achieved performance and its relation to the predefined service levels. This included information about the number of client calls received, the average waiting time, the number of incidents created by the Help Desk, and the number of incidents which were not resolved within the predefined time and/or quality constraints.

Equipment

Different kinds of hardware and software equipment were used in the work of the ICT Help Desk. However, several equipment items were critically important for the effectiveness and efficiency of the work of the department. These items were the computer telephony system used at the department, the call database, the standard-solutions database, the incident database and the equipment available at the individual workplaces in the department. The following paragraphs provide more information about these items of equipment, taking into account the goals and the specific requirements of the test case.

The ICT Help Desk department used a Lucent Centre Vue® computer telephony system for handling client calls. The system offered the possibility to receive client calls and distribute them among the available agents, or place them in a special waiting queue in case all the agents were occupied. The selection of the agent to handle the call was carried out on a round-robin basis from the list of available agents. The waiting queue could hold up to 999 calls simultaneously and provide the clients with additional information or a pre-recorded melody while waiting to be served. An important part of the functionality of the system was its ability to keep track of the number of call waiting in the queue, the time of receiving a call, the time the call is answering it by an agent or abandoning it by the client, and the time of ending an answered call. This information could easily be imported into, e.g., a spreadsheet application, and was used for obtaining data about key performance parameters of the Help Desk such as total number of received calls, number of calls served within a predefined time period, average waiting time in the telephony system queue, shortest and longest waiting time in the queue, and the number and average waiting time for abandoned calls.

A call registration database tool was used to store information about the client calls received at the ICT Help Desk. Among the information stored in the database were the time of receiving the call, the name, telephone number, department and location of the caller, a description of the disturbance and an exact scenario for its reproduction, the affected hardware items and/or software applications. In case a standard solution was available for the disturbance it was also recorded in the database along with information whether the application of the solution lead to resolving the disturbance, or an incident had to be created. In the latter case the number of the created incident was also recorded. The information recorded in the call registration database was used for creating an incident, for reference during the incident resolution, as well as for later reference and reporting.

A standard solutions database was used for storing (sequences of) actions that could be used for resolving common and/or minor disturbances. The actions used as standard solutions were relatively simple and were carried out either by the user or remotely by the Front Office Call Agent. The database contained extended searching capabilities, including searching on affected hardware item or software application and on the description of the disturbance. The database was held up-to-date with input from the support departments, projects for implementing new applications and/or infrastructure and the front office call agents themselves. In some cases it was also used to store additional information about a disturbance that had to be obtained from the client in order to speed up the subsequent resolution process.

An incident registration database called *Infoman* was used as a central repository for creating, storing and managing incidents created as a result of a reported disturbance. The database was installed on a mainframe computer and special measures were taken (e.g., shadowing, disk mirroring and frequent backups) to ensure its high availability. It provided interfaces to all departments involved in the incident resolution and provided means for creating an incident, assigning it to a specific department, tracking the handling of an incident, changing its status, as well as for archiving incidents and reopening them at a later time if necessary. The incident records in the database contained all relevant information about an incident including description of the disturbance, details about its impact and priority and the affected hardware and/or software components, the diagnosis of the cause(s) of the disturbance, the actions taken in order to resolve it, as well as information about the quality of the resolution. The incident database was a core tool used in the work of the Help Desk, and its availability and performance were of critical importance for the handling of the client calls in a timely, effective and efficient manner.

The workplaces at the ICT Help Desk department were equipped with a Microsoft Windows NT® based personal computer and a telephone unit connected to the Centre Vue® computer telephony system. The telephone unit offered the possibility for passing on (communicating) the status of the agent (active/inactive/busy/free) to the telephony system, receiving calls and redirecting them if necessary, as well as for handling several calls simultaneously. The personal computer offered the interfaces and emulators necessary to realize the access to the tools described above, as well as other applications as e-mail clients, Microsoft Office, Inter/Intranet and tools for remote system management used for applying standard solutions.

6.3.2.2 Quantitative Process Data

Next to the structural data, quantitative data about the work of the ICT Help Desk were also gathered. A distinction was made among *client call data*, *incident data* and *activity duration data*. These data are presented in the following sections.

Client Call Data

Five characteristics of the incoming client calls important for the building of a simulation model of the ICT Help Desk were identified. These were the *frequency of arrival* of client calls at the ICT Help Desk, their *priority*, the *type of disturbance* they referred to, as well as the *percentage solved at the ICT Help Desk* and *percentage from all disturbances* for disturbances of a specific type.

The average *frequency of arrival* of client calls per hour and its standard deviation are given in table 6.1. The data in the table are based on data from the computer telephony system of the ICT Help Desk. Interviews with the Front Office Call Agents were used to validate the calculated average values. These values were calculated from the data over four weeks in April 2000. The load during this period was considered by to be representative of the load during the normal working periods of the year (thus not periods with, e.g., vacation or a lot of holidays). The data in the table were estimated to cover 95% of the actual situation.

As it can be seen from the table, the frequency of arrival depended strongly on the day of the week and the period of the day. On Mondays and Fridays the intensity was lower than during the rest of the week, and the amount of calls on Monday was a little higher than on Friday. The amount of calls on Tuesday, Wednesday and Thursday was almost equally distributed, with Tuesday and Thursday being on the average the busiest days of the week. With regards to the period of the day, the intensity of call arrival was highest from approximately 09.30 till 11.30 a.m. and 13.30 and 17.30 p.m., while from 07.30 till 09.30 a.m., 11.30 till 13.30 (lunch break) and 17.30 till 21.30 it was considerably lower.

Period of the day	*Day of the week*				
	Monday	Tuesday	Wednesday	Thursday	Friday
07.30 – 09.30	9 (3)	17 (9)	14 (9)	16 (11)	6 (3)
09.30 – 11.30	37 (12)	68 (20)	56 (19)	62 (20)	42 (15)
11.30 – 13.30	5 (3)	9 (6)	7 (5)	8 (5)	3 (2)
13.30 – 17.30	20 (8)	34 (12)	28 (12)	32 (14)	12 (7)
17.30 – 21.30	3 (2)	4 (3)	4 (2)	4 (3)	2 (1)

Table 6.1: The average frequency of call arrival and its standard deviation (calls per hour)

The *priority* of the client calls, the *type of disturbances* they referred to, the *percentage solved at the ICT Help Desk* by using a standard solution as well as the *percentage from all disturbances* for a specific type of disturbance are given in table 6.2. The values in the table are average values based on data from the call and incident management databases and validated by means of questionnaires and interviews with the Front Office Call Agents. As it can be seen from the table, there was a relation between the type of the disturbance and its priority, i.e., certain disturbances had a minor impact and a big percentage of them had a lower priority, while others had a big impact and the majority of them had a higher priority. There was also a relation between the type of disturbance and the percentage of disturbances of this type solved at the ICT Help Desk by applying a standard solution. A relatively big percentage of the disturbances with a minor impact were solved at the ICT Help Desk against a relatively small percentage of the disturbances with a big impact.

Type of disturbance	*Percentage from all disturbances*	*Priority (%)*					*Percent solved by the Help Desk*
		0	*1*	*2*	*3*	*4*	
Printer	28	0	0	67	27	6	42
E-mail	12	0	24	61	6	9	67
Mouse	5	0	0	74	26	0	1
Screen	6	0	0	99	0	1	2
Keyboard	8	0	0	99	0	1	2
Server	4	0	22	46	27	5	3
Browser	3	0	0	82	12	6	86
MS Office	12	0	0	78	19	3	89
Password	2	0	0	100	0	0	99
Network	5	34	45	17	3	1	4
PC (Startup)	7	0	0	72	23	5	9
Core applications	3	57	30	12	1	0	3
Terminal	3	2	5	86	5	2	74
Lotus Notes	2	0	0	77	21	2	51

Table 6.2: Client call characteristics

Incident Data

The characteristics of the incidents arriving at the ICT Help Desk which were important for the building of a simulation model were similar to the characteristics of the client calls described above. The incidents had two sources: the client help desks and the support departments within the IT Production department. The incident data for each of these sources are presented below.

The frequency of arrival of *incidents created by client help desks* is given in table 6.3. The pattern of arrival of client calls described above (depending on the day of the week and the period of the day) was also applicable for the frequency of arrival of this kind of incident. However, the frequency of arrival of incidents was lower than the frequency of arrival of client calls due to the fact that the client base served by the client help desks was much smaller, on the one hand, and the fact that a number of disturbances were solved directly at the client help desks, on the other.

Period of the day	*Day of the week*				
	Monday	Tuesday	Wednesday	Thursday	Friday
07.30 – 09.30	2 (1)	5 (2)	5 (3)	6 (3)	2 (1)
09.30 – 11.30	6 (3)	8 (4)	7 (4)	8 (4)	5 (2)
11.30 – 13.30	2 (1)	3 (2)	2 (1)	3 (2)	2 (1)
13.30 – 17.30	5 (2)	7 (4)	6 (4)	7 (4)	4 (2)
17.30 – 21.30	2 (1)	3 (1)	2 (1)	4 (2)	2 (1)

Table 6.3: The average frequency of incident arrival and its standard deviation (incidents per hour)

The most common types of disturbances reported in the incidents from the client help desks, their priority, the percentage solved at the ICT Help Desk by using a standard solution as well as the percentage of incidents for a specific type of disturbance from all incidents from the client help desks are given in table 6.4. The data in the table are based on data from the incident database from the same period as the client call data described above.

Type of incident	*Percentage from all incidents*	*Priority (%)*					*Percent solved by the Help Desk*
		0	*1*	*2*	*3*	*4*	
Printer	36	0	0	71	29	0	40
E-mail	16	0	24	75	1	0	61
Server	5	0	21	57	22	0	2
Browser	4	0	0	89	11	0	79
MS Office	15	0	0	91	9	0	82
Network	7	40	49	10	1	0	2
PC (Startup)	9	0	0	92	8	0	7
Core applications	4	59	32	8	1	0	1
Terminal	3	5	4	90	1	0	65
Lotus Notes	1	0	0	94	6	0	46

Table 6.4: Types of incidents and their characteristics

As it can be seen from the table, the incidents from the client help desks contained a smaller number of disturbance types compared to the client calls. The number of incidents solved by the ICT Help Desk was also lower. This was due to the fact that certain types of incidents were resolved directly by the client help desks.

The frequency of arrival of (resolved) *incidents from the support departments* depended on the number and/or type of incidents waiting for resolution at a specific point in time. However, for the different disturbance priorities there were predefined resolution periods. For priority 1 disturbances this period was "*as soon as possible, but no later than 4 hours*", for priority 2 – "*8 hours, or no later than one working day*", for priority 3 – "*2 working days*", for priority 4 – "*1 week*", and for priority 5 – "*2 months*". It was estimated that in general, approximately 9 percent of the incidents had to be escalated because of expired resolution period. Of the escalated incidents approximately 5% had priority 2, 65% - priority 3 and 30% - priority 4. Priority 5 incidents were not escalated.

Activity Duration Data

As explained in chapter 4, a task is defined in this research as a logical unit of work consisting of one or more activities, which are considered to be atomic pieces of work from the point of view of simulation modeling. As a result of this the duration of an activity is relatively stable and we can obtain an estimation of it, while the duration of a task depends on the processed information object and the exact activities that have to be carried out. Therefore, we have chosen to gather data about the duration of activities rather than the duration of tasks. In case a task consists of one activity it carries the name of the task.

The data about the duration of the different activities carried out at the workplaces of the ICT Help Desk were gathered by using questionnaires and interviews. A minimum, average and maximum duration were specified for the duration of each activity. For each of these durations a standard deviation was defined, as well as the percentage of time when it corresponded to the actual duration. The durations of the activities carried out at the four workplaces of the ICT Help Desk (described in the previous sub-section) are presented below.

The durations of the activities (in minutes) carried out at the *Front Office Call Agent* workplace of the ICT Help Desk are given in table 6.5. The frequency of carrying out these activities depended on the frequency of client calls arrival and the number of available Call Agents.

Activity	*Min.*	*Avg.*	*Max.*
Answer call	0.25 (0.05) – 5%	0.5 (0.25) – 80%	1 (0.5) - 15%
Register call	1 (0.5) – 25%	1.5 (0.5) – 70%	2.5 (0.5) – 5%
Diagnose call	0.5 (0.25) – 30%	1 (0.5) - 60%	2 (0.5) – 10%
Check for standard solution	0.5 (0.25) – 35%	0.75 (0.5) – 60%	1.5 (0.5) – 5%
Apply standard solution	2 (0.5) – 20%	5 (1.5) – 65%	8 (2) – 15%
Create incident	1.5 (0.5) – 45%	2 (0.5) – 50%	3 (0.5) – 5%
Escalate incident	2 (1) – 35%	4 (2) - 55%	10 (4) – 10%
Close call	0.25 (0.05) – 65%	0.5 (0.25) – 30%	1 (0.5) – 5%

Table 6.5: Durations of the activities of the *Front Office Call Agent* workplace

The durations of the activities (in minutes) carried out at the *Front Office Client Queue Agent* workplace of the ICT Help Desk are given in table 6.6. The frequency of carrying out the activities depended on the frequency of arrival of incidents from the client help desks. As mentioned above, there was one person working at this workplace.

Activity	*Min.*	*Avg.*	*Max.*
Diagnose incident	1.5 (0.5) – 30%	2.5 (0.5) - 65%	5 (1.5) – 5%
Check for standard solution	0.5 (0.25) – 35%	0.75 (0.5) – 60%	1.5 (0.5) – 5%
Apply standard solution	3.5 (0.5) – 40%	5 (0.5) – 45%	9 (3) – 15%
Send incident	2(1) – 65%	3(1) – 30%	5(2) – 5%
Escalate incident	2 (1) – 35%	4 (2) 55%	10 (4) – 10%
Close incident	0.5 (0.25) – 60%	1 (0.25) – 35%	2 (0.5) – 5%

Table 6.6: Durations of the activities of the *Front Office Client Queue Agent* workplace

The durations of the activities carried out at the *Back Office Agent* workplace of the ICT Help Desk are given in table 6.7. The frequency of carrying out these activities (except for the "c*heck open incidents*" activity) depended on the frequency of arrival of incidents resolved by the support departments. In about 30% of the cases a call to the client was necessary in order to verify the quality of the incident resolution. The "c*heck open incidents*" activity was carried out on a regular basis once per hour, provided that there were no incidents waiting for solution verification and closure.

Activity	*Min.*	*Avg.*	*Max.*
Check open incidents	3 (2) – 15%	15 (6) – 75%	20 (10) - 10%
Check system parameters	2 (1) – 30%	4 (2) – 65%	6 (3) – 5%
Call client	1.5 (0.5) – 40%	2.5 (1.5) - 50%	4 (2.5) – 10%
Send back incident	0.5 (0.25) – 20%	1 (0.5) – 75%	2 (0.5) – 5%
Escalate incident	2 (1) – 35%	4 (2) 55%	10 (4) – 10%
Close incident	0.25 (0.05) – 65%	0.5 (0.25) – 30%	0.75 (0.5) – 5%

Table 6.7: Duration of the activities of the *Back Office Agent* workplace

The durations of the activities carried out at the Team *Leader ICT Help Desk* workplace of the ICT Help Desk are given in table 6.8. Most of these activities were carried out on a regular basis, therefore the frequencies of carrying out the activity are also included in the table. The frequency of the "*escalate incident*" activity is also included in the table, however, it is carried out on an *ad hoc* basis and is triggered by an incident escalation from one of the other workplaces at the Help Desk.

Activity	Min.	Avg.	Max.	Frequency
Coordinate Help Desk tasks	15 (10) – 75%	25 (15) – 15%	35 (15) – 5%	4 p/d
Allocate resources	10 (5) – 65%	15 (10) – 25%	30 (15) – 10%	2 p/w
Monitor perfornance	10 (5) – 65%	15 (10) -40%	25 (15) – 5%	1 p/d
Escalate incidents	0.5 (0.25) – 35%	0.75 (0.5) – 60%	1.5 (0.5) – 5%	4 p/w
Provide advice	60 (30) – 25%	150 (45) – 70%	180 (60) – 5%	1 p/w
Attend meetings	45 (15) – 55%	60 (30) – 35%	75 (30) – 10%	3 p/w
Report on performance	30 (15) – 70%	45 (15) - 25%	60 (30) – 5%	1 p/w

Table 6.8: Duration of the activities of the *Team Leader ICT Help Desk* workplace

6.3.3 Step 3: Conceptual model development

The development of the conceptual model of the functioning of the ICT Help Desk consisted of specifying the classes that were used to represent the identified process elements and defining the relationships of these classes. It also included a mapping of the process logic that comprised of the communication model, process model and workplace model described in chapter 5. In line with this, in the following sections information is provided about the *classes and their relationships,* as well as about the *process logic of the ICT Help Desk.*

Classes and their Relationships

Based on the structural data presented in sub-section 6.3.2.1 the classes that were used to build the simulation model of the ICT Help Desk were specified. These classes were divided into three main categories: classes representing information objects*, classes representing workplaces and classes representing equipment.

As explained above, six basic information objects were identified in the work of the ICT Help Desk: These were the *Client Call, Incident, Incident Escalation, Standard Solution, Solution Check* and *Solution Information.* The last three of these could be represented by the *Information Object* class described in chapter 4. However, in order to represent the first three information objects, the *Information Object* class needed to be extended to include additional attributes. Therefore, based on this class, for each of the first three information objects a new class was defined which added the specific attributes necessary to represent them. This is depicted in fig. 6.2.

* The term *information object* is used here to denote the corresponding process element defined in chapter 4, and should not be confused with the term *object* used to denote an instance of an *object class* in the object-oriented terminology.

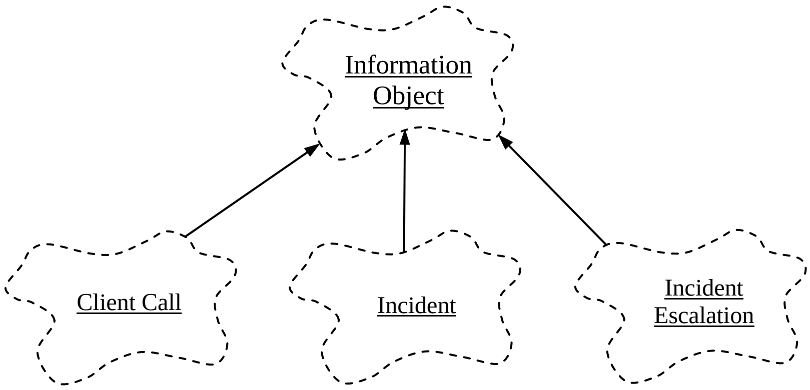

Figure 6.2: The three new *Information Object* classes

The specifications of the three new classes and the additional attributes they include are given in fig. 6.3.

Object class *Client Call*	**Object class** *Incident*	**Object class** *Incident Escalation*
Inherits from	**Inherits from**	**Inherits from**
Information Object	*Information Object*	*Information Object*
Attributes	**Attributes**	**Attributes**
Priority	*Priority*	*Incident id*
Disturbance	*Disturbance*	*Escalation type*
	Status	

Figure 6.3: The specification of the three new *Information Object* classes

In order to represent the workplaces of the ICT Help Desk four new classes had to be defined. These classes corresponded to the workplaces *Front Office Call Agent, Front Office Client Queue Agent, Back Office Agent* and *Team Leader ICT Help Desk* described in the previous section. The classes inherited the structure, attributes and methods of the *Workplace* class described in chapter 4, however, they provided a concrete definition of its *Tasks* attribute. The four new classes are depicted in fig. 6.4.

The definition of the *Tasks* attribute for each of the classes corresponded exactly to the tasks for the respective workplace defined in sub-section 6.3.2.1. Therefore, no further specification of the classes is provided here.

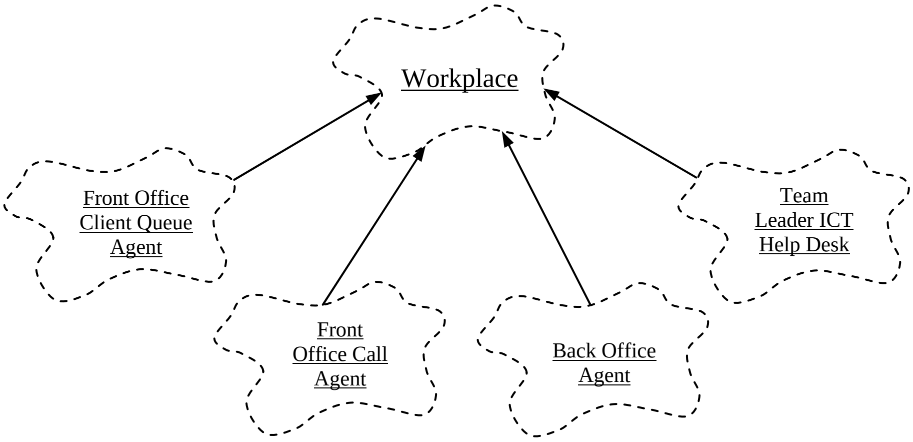

Figure 6.4: The four new *Workplace* classes

Two of the equipment items used in the work of the ICT Help Desk were included explicitly in the simulation model. These were the *Computer Telephony System* and the *Incident Database.* In order to represent them two new classes were defined. These classes inherited the structure, attributes and methods of the *Equipment* class described in chapter 4, however, two new methods were added to each of them in order to represent the logic used to process information items. The two new classes are depicted in fig. 6.5.

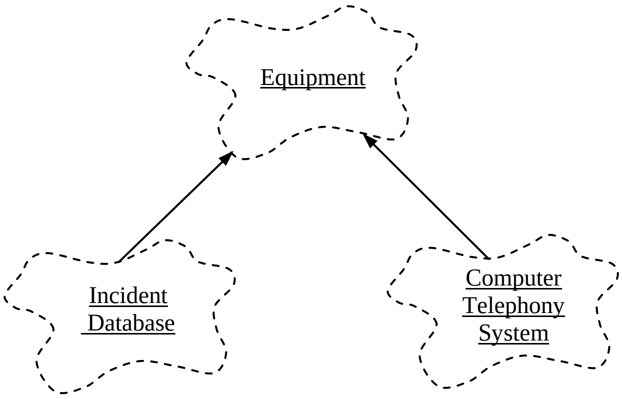

Figure 6.5: The two new *Equipment* classes

The specification of the two classes and the methods added to them are depicted in fig. 6.6. As it can be seen from the figure, a *Process Client Call* method was added to the *Computer Telephony System* class. This method represented the logic necessary for receiving the client calls and dispatching them to a free Front Office Call Agent, or placing them in a queue in case all agents were busy. A *Process Incident* method was added to the *Incident Database* class representing the logic necessary to process incoming incidents and dispatch them to the correct workplace or department. A *Process Data Request* method was added to both classes representing the logic necessary for processing request for data about respectively client calls and incidents.

Object class *Computer Telephony System*	**Object class** *Incident Database*
Inherits from	**Inherits from**
Equipment	*Equipment*
Methods	**Methods**
Process Client Call ()	*Process Incident ()*
Process Data Request ()	*Process Data Request ()*

Figure 6.6: The specification of the two *Equipment* classes

The interactions of the object classes representing the workplaces and equipment of the ICT Help Desk are captured in the interaction diagram depicted in fig. 6.7. The interactions are based on the description of the workplaces and equipment provided in sub-section 6.3.2.1. The information objects exchanged in the interactions are not explicitly included in the figure. They are captured in the models of the process logic presented below.

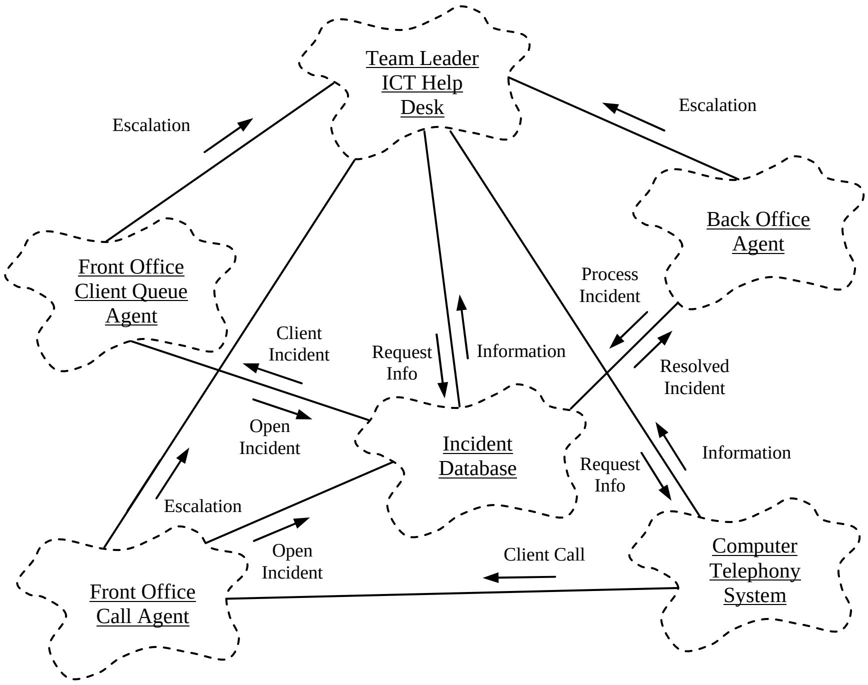

Figure 6.7: The interaction diagram of the ICT Help Desk

Process Logic of the ICT Help Desk

The process logic of the ICT Help Desk was captured using the *communication model*, the *process model* and the *workplace model* presented in the previous chapter.

The *communication model* captured the exchange of information that took place as part of the work of the ICT Help Desk. It comprised of the workplaces and the equipment included in the conceptual model as well as the information objects exchanged in their interaction. It also included the external parties which provided input to or received output from the ICT Help Desk. These were the *Clients* which reported disturbances and provided information about their resolution, the *Client Help Desks* which sent incidents to the ICT Help Desk and the *Support Departments* which provided second- and third-line support for the incidents of the ICT Help Desk. The communication model is depicted in fig. 6.8. An explanation of the abbreviations used to denote the names of the information objects is provided in the legend included in the figure. The communication model formed the basis for defining the user view of the simulation model of the ICT Help Desk described later in this chapter.

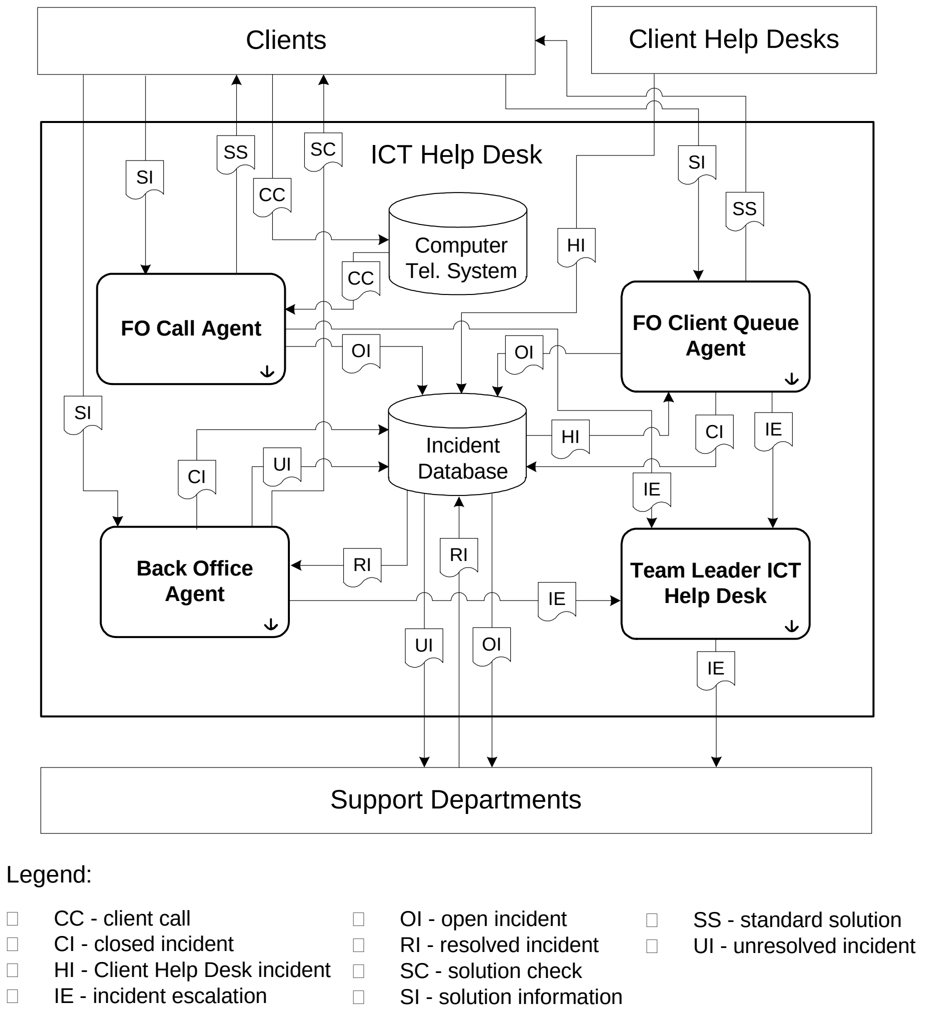

Figure 6.8: The communication model of the ICT Help Desk

The *process model* of the ICT Help Desk was built in order to capture the tasks carried out at the Help Desk, the workplaces at which they were carried out, the sequence in which they were carried out and the conditions governing this sequence. The information objects serving as an input to or output of a task were also represented in the model. The external parties providing input to or receiving output from the ICT Help Desk were also included in the model. The process model of the ICT Help Desk is represented in fig. 6.9. The model was built using the notation described in the previous chapter. The abbreviations used to denote the names of the information objects are the same as the ones used in fig. 6.8.

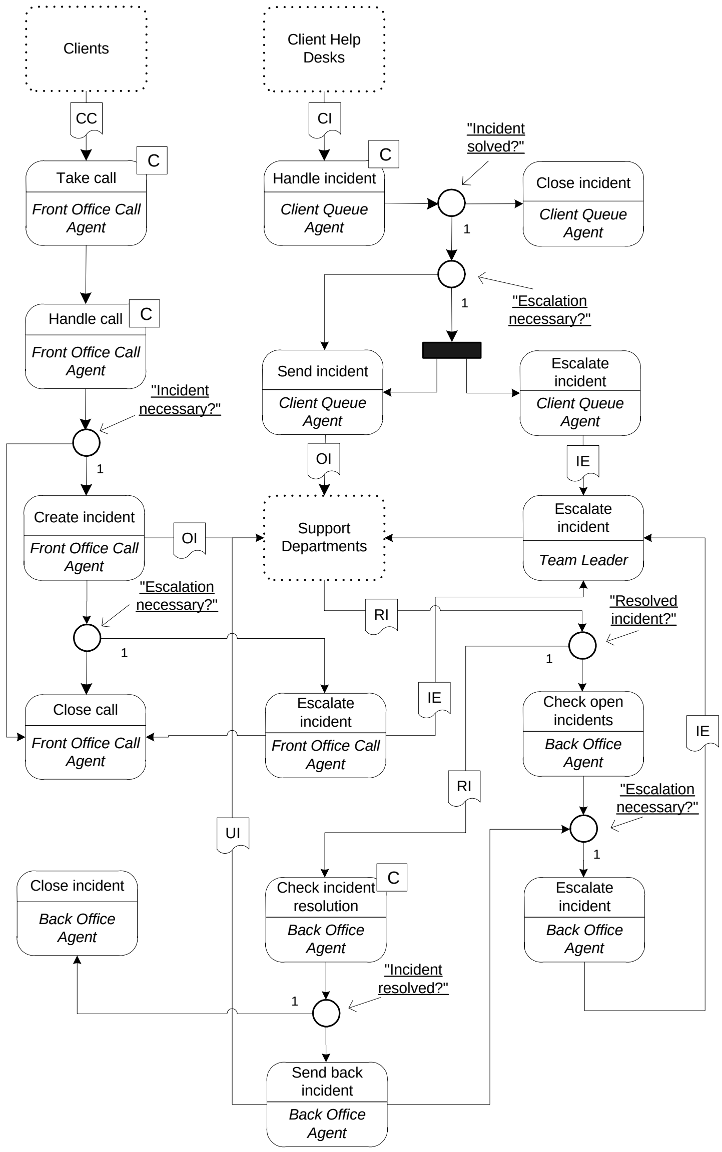

Figure 6.9: The process model of the ICT Help Desk

The *workplace model* was used to capture the tasks and activities carried out at the individual workplaces of the ICT Help Desk, the logic and conditions governing their execution, the used equipment as well as the exchanged information objects. The external parties providing input to or receiving output from a workplace were also included in the respective workplace model. The developed workplace models of the *Front Office Call Agent*, *Front Office Client Queue Agent* and the *Back Office Agent* are depicted in figures 6.10, 6.11 and 6.12 respectively. Due to the fact that the work of the *ICT Help Desk Team Leader* was not in the main focus of the test case and his tasks were modeled only to the extent necessary to represent incident escalation, no separate workplace model was built for the this workplace.

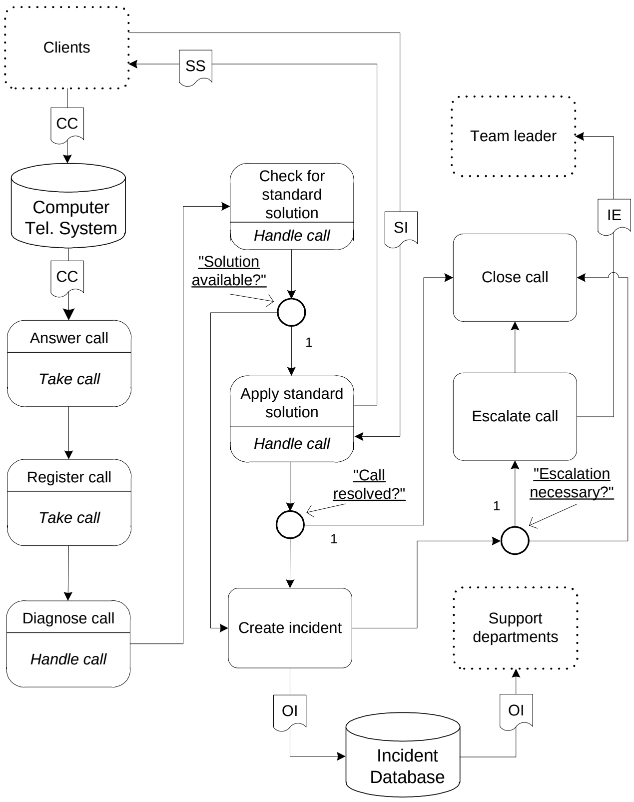

Figure 6.10: The workplace model of the *Front Office Call Agent*

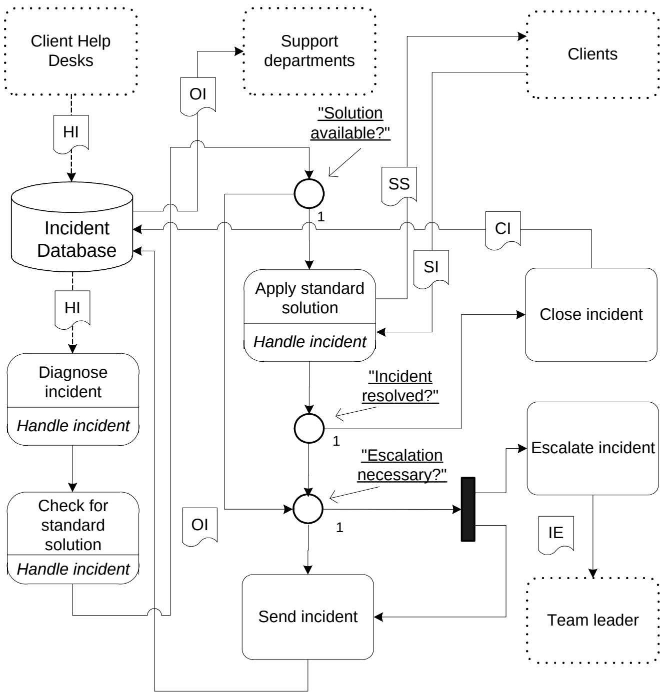

Figure 6.11: The workplace model of the *Front Office Client Queue Agent*

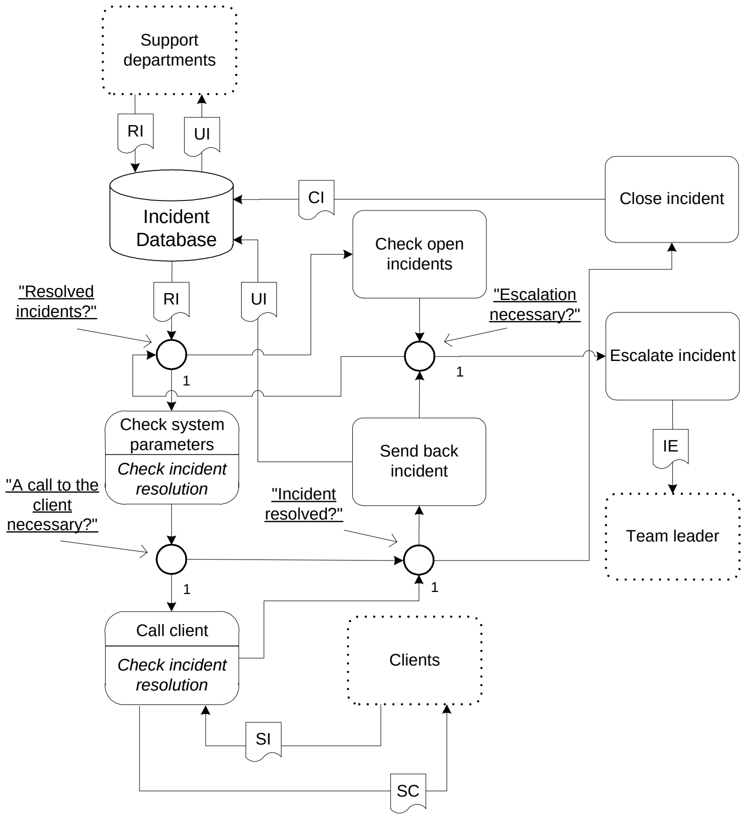

Figure 6.12: The workplace model of the *Back Office Agent*

6.3.4 Step 4: Build the simulation model

Based on the conceptual model described in the previous sub-section and the gathered structural and quantitative process data the simulation model of the ICT Help Desk was built using the objects of the object class library for ICT management simulation described in chapter 4. This included building the model structure and logic, filling in the model data, and the verification and validation of the model. These activities are described in the next sections.

Building the Model Structure and Logic

The structure of the model was build using the information objects, workplaces and equipment described in the previous section. The model included seven IT workers working at the *Front Office Call Agent* workplace, two IT workers working at the *Back Office Agent* workplace, one IT worker working at the *Front Office Client Queue* workplace and one IT worker at the *ICT Help Desk Team Leader* workplace. The model also included two equipment items representing the *Lucent* computer telephony system and the incident database *Infoman* due to the key role they played in the work of the Help Desk and in its communication with the clients, client help desks and the support departments. The latter three were represented in the model only to the extent necessary to capture their impact on the work of the Help Desk.

In order to achieve a clear visualization of the information objects exchanged and processed in the model icons with different shapes and/or color were used to represent the different types of objects and their states. In this way, different icons were used to represent the client calls, the client incidents, and the open, resolved and unresolved incidents. In order to distinguish among the priorities of these information objects, different colors were used for the different priorities of the objects. A special icon was also used to denote call and incident escalation.

Additional logic was built into the model in order to capture the distribution of the incoming calls among the call agents and the distribution of arriving resolved incidents among the back office agents. This logic took into account the availability of the agents, the used round-robin distribution principle and the principle of processing the calls and/or incidents with the highest priority.

Five performance indicators were also built into the model based on the actual performance indicators used in the work of the ICT Help Desk. These were the percentage of waiting calls in the queue of the computer telephony system, the percentage of the calls served within two seconds, and the average workloads of the *Front Office Call Agents*, the *Front Office Client Queue Agent* and the *Back Office Agents* directly related to the handling of incidents and calls.

The user view of the developed simulation model of the work of the ICT Help Desk is depicted in fig. 6.13.

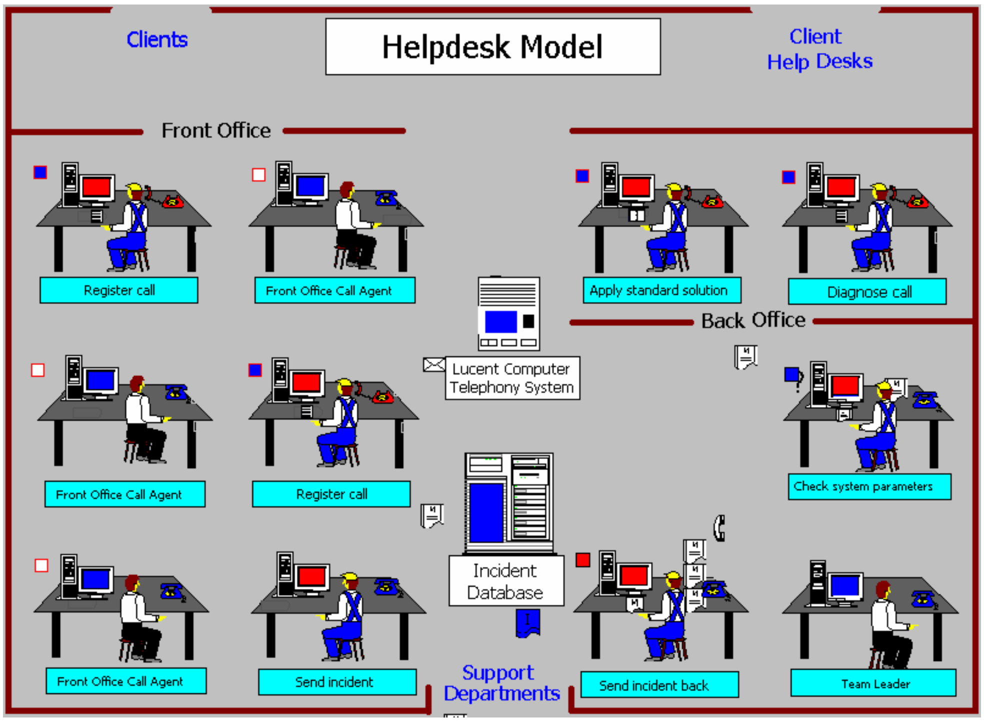

Figure 6.13: The user view of the ICT Help Desk simulation model

Filling in Model Data

The data filled into the model were based on the data presented in sub-section 6.3.2.2. A distinction was made among data about the frequency of arrival of client calls and incidents, data about their type, priority and the percentage for which a standard solution was available, data about processing times at the different workplaces and the different courses of action taken.

The data about the frequency of arrival of client calls and incidents were based on the data given in tables 6.1 and 6.3 respectively. A random number generator with a *triangular distribution* was used to generate the arrivals. A different generator was defined for each of the days of the week and the periods of the day. The mean value and the deviation provided in the tables were used to calculate the minimum, average and maximum values necessary for determining the distribution. The used time units in the model corresponded to one minute in the real-life situation.

The data about the type of disturbance, its priority and the percentage solved by the Help Desk for the client calls and incidents were based on the data given in tables 6.2 and 6.4 respectively. These data were assigned to special attributes of the model entities representing the arriving calls and incidents. The values of these attributes were assigned in a stochastic way, and the probabilities for each value were based on the percentages given in the tables.

The data about the processing times at the different workplaces were based on the data given in tables 6.5 to 6.8. A separate random number generator using a *normal distribution* was used to generate the processing times for each task and/or activity. In each generator the values for the mean value and the standard deviation were based on the corresponding values from the aforementioned tables.

Data about the percentage of incidents that needed to be send back for further resolution, as well as the percentage of the escalated calls and incidents were also included in the model based on the data provided in section 6.3.2.2.

Model Verification

Structured walkthroughs of the model logic, tracing model operation, special modeling conditions and observation of certain model parameters were used to verify the functioning of the simulation model.

Structured walkthroughs of the model logic were carried out with the participation of representatives of the four workplaces of the ICT Help Desk described above. The scope of the model and the made assumptions were described and the modeling of the different parts of the work of the Help Desk (e.g., call handling, incident handling, call escalation) was explained, and the work of the simulation model was demonstrated.

Tracing of the model operation was used to ensure that it corresponded to the logic captured in the communication, process and workplace models described above. The tracing was carried out by executing the model step by step and visualizing the active information object and the active module of the model logic, as well as by checking the values of information object attributes and model variables to verify their correct assignment.

Special modeling conditions and observation of model parameters were also used to verify the model. This comprised the generation of a single information object of a certain type and following its processing through the model, as well as generating high workloads for the different workplaces in the model in order to ensure their correct functioning. Model parameters like the number of information objects in certain queues of the model and their average waiting time, or the percentage of time spent on the different tasks and activities defined for a specific workplace were observed in order to ensure the model was functioning as expected.

Model Validation

The model was validated using face validation with subject matter experts and replicative validation of the model output.

The face validation with subject matter experts included demonstrating the functioning of the model and the generated output data to people working at the different workplaces of the ICT Help Desk. This lead to the fine-tuning of several aspects of model behavior.

The replicative validation was carried out by calculating the difference of the average values produced by the model and the empirical values for the performance parameters described above. This difference was calculated by performing t-tests on these values for 25 model replications, where each replication had a span of one working week. As mentioned above, the gathered quantitative data were considered to cover 95% of the work of the Help Desk, therefore a level of confidence of 95% was used for performing the t-tests. It was concluded that there was no significant difference between the output values generated by the model and the empirical ones.

6.3.5 Step 5: Experimentation and results interpretation

The working of the simulation model of the ICT Help Desk can be examined by installing the model from the CD-ROM available as an appendix to this book (see appendix B). In order to illustrate the benefits of using the developed simulation template part of the model has been built using the simulation constructs from the template while another part has been built using the standard simulation blocks offered by *ARENA*®. Below we summarize the experimentation with the model and the obtained results in relation to the goals of the test case.

As explained in sub-section 6.3.1 one of the goals of the test case was to estimate the impact of the planned change in the work of the Help Desk on the speed and quality of client call and incident handling. The change consisted of letting one of the Back Office agents perform Front Office tasks, increasing in this way the number of IT workers at the Front Office to eight, while leaving one IT worker to perform Back Office tasks. No special redistribution of the tasks between the Front Office and the Back Office was initially planned, however, in case the new setting would lead to an unacceptable increase in the time necessary to handle resolved incidents, such a re-distribution was considered a viable alternative.

In order to estimate the impact of the planned reorganization the model of the ICT Help Desk was changed so as to reflect the new situation. A new *Front Office Call Agent* was added to the model, while one *Back Office Agent* was removed from the model. The logic for distributing calls and incidents was changed to reflect the new model structure. The user view of the changed model is depicted in fig. 6.14.

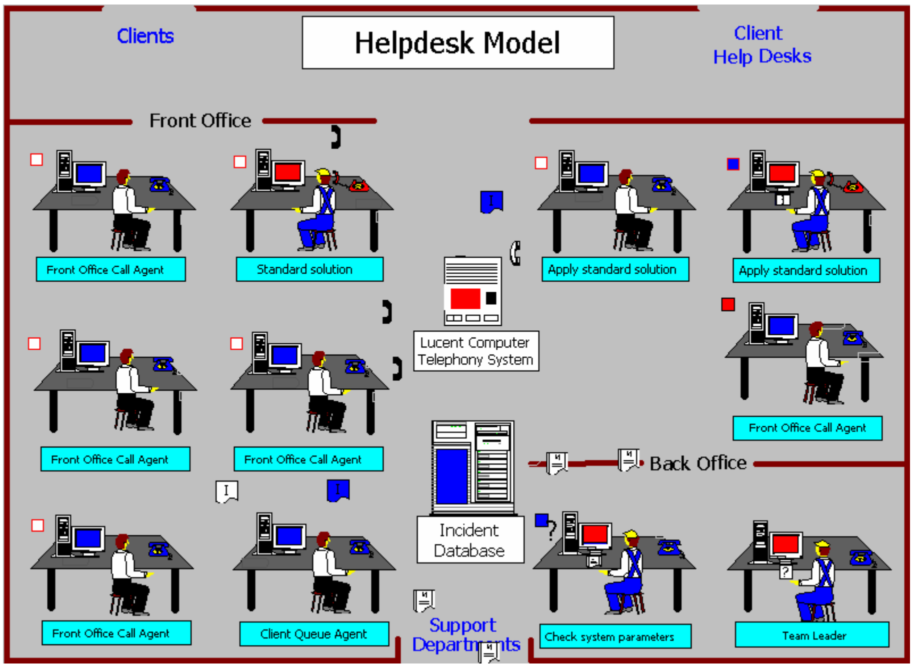

Figure 6.14: The user view of the changed ICT Help Desk simulation model

The changed model was run with the same input data, conditions and assumptions as the original model. The difference in the behavior of the two models was determined based on the values of the performance parameters described above, which were generated by the models. However, the workload of the *Front Office Client Queue Agent* was left out of consideration as the reorganization did not have a direct impact on his work. The original and the changed models were run for 25 replications with a span of one week in the real-life processes and the average values of the generated output parameters were calculated. On the basis of the difference in these parameters the expected impact of the reorganization on the work of the Help Desk was determined.

The average values of the model parameters for the original and the changed model, as well as their difference are given in table 6.9.

	Percentage of calls waiting in queue (%)	*Percentage of calls answered within 2 sec (%).*	*Average workload Front Office Call Agent (%)*	*Average workload of Back Office Agent (%)*
Original model	19	87	62.67	51.92
Changed model	14	91	51.98	78.46
Difference (%)	26%	5%	17%	51%

Table 6.9: The values and difference of the parameters of the new and the changed model

Based on the data provided in the table, it can be concluded that the planned reorganization would lead to decreasing the number of calls waiting in the queue of the computer telephony system with 26%, while increasing the percentage of calls served within 2 seconds to 91%. The average percentage of time during which the *Front Office Call Agents* are carrying tasks directly related to the handling of incoming client calls would decrease from 62.67% to 51.98%, while the average percentage of time the *Back Office Agent* would spend on handling resolved incidents would increase from 51.92% to 78.46%. The workload of the *Back Office Agent* had not doubled due to the fact that the frequency of checking open incidents by the agent remained the same.

6.4 Conclusions

In this chapter the application of the conceptual basis and the set of modeling constructs described in chapter 4, as well as the approach for ICT management simulation described in chapter 5 was presented based on a test case in a real-life situation. The test case was carried out in a financial services organization and focused on the work of its ICT Help Desk. The purpose of the case was twofold: first, it had to illustrate the way in which the elements mentioned above can be applied in practice and validate their usability and applicability, and second, it had to provide insight into the work of the ICT Help Desk, illustrate the way in which client calls and incidents were handled, model the different tasks and activities carried out at the Help Desk, and provide an estimation of the impact of the planned reorganization of the Front and Back Office on the work of the Help Desk and the service levels. With regards to this, the following conclusions can be made:

- The test case illustrated the way in which the conceptual framework can be applied for identifying the basic objects that are part of the processes under investigation and for defining their characteristics and functionality.
- The way in which the object classes of the object class library for ICT management simulation can be used for building a simulation model was explained and their application for building a simulation model in a real-life situation was described.
- The way in which the approach for building ICT management simulation models can be used in practice to carry out a simulation study was described, the application of its steps was demonstrated and the way of building and using the different models that are part of it was explained.
- By modeling and visualizing the tasks and activities carried out at the ICT Help Desk, the used equipment, the processed information objects, as well as the interaction of the Help Desk with the clients and client help desks on the one hand, and the support departments, on the other, insight into the functioning of the Help Desk was provided and the way in which client calls and incidents were handled was explained.
- The developed simulation model of the ICT Help Desk was used to provide quantitative data about the impact of the planned reorganization on the work of the Help Desk and an estimation of the expected changes in the workloads of the different IT workers and the speed and quality of handling client calls was provided.

In the next chapter a second test case is presented, which demonstrates the application of the conceptual basis, the modeling constructs and the approach for ICT management simulation described in chapters 4 and 5 in another practical situation.

Chapter 7

Simulating ICT Management Processes: Test Case B

7.1 Introduction

In chapters 4 and 5 of this thesis a framework and an approach for simulating ICT management processes were presented, the ideas behind them were explained and their components were described. The way in which they can be applied for building an ICT management simulation model was illustrated in chapter 6 using a test case based on a real-life implementation of an ICT Help Desk in the IT department of a big consumer bank in The Netherlands.

In this chapter a second test case is described in which the framework and the approach are applied for building a simulation model of a real-life ICT management process implementation. Similarly to chapter 6, the goal of this chapter is to describe the way in which the framework and the approach for simulating ICT management processes can be applied in practice and to validate the ideas, techniques and elements presented as part of them.

The structure of the chapter is as follows. In section 7.2 a description of the test case is provided based on the step-by-step approach described in chapter 5. In section 7.3 conclusions about the results of the test case and the application of the framework and the approach for simulating ICT management processes are presented.

7.2 Case B: A Public Services Organization

The second test case was carried out at the ICT department of a public services organization in The Netherlands. This was the Central Service for Information Provisioning (CSIP) department, which provided services ranging from e-mail and networking to specialized applications and (internationally distributed) databases to mobile telephony and communication. The CSIP department consisted of several sub-departments, where ICT management, development of new products and services, as well as project management and control were carried out. The ICT management departments of the CSIP department are depicted in fig. 7.1. They can be described as follows:

- *Service Management* – this department was responsible for the coordination of the ICT services delivery and service level management. This included discussing the information needs of the users and the formulation of service requests, initiating and supporting projects for delivering new or changed ICT services, defining service level agreements (SLAs), monitoring the achieved service levels and taking corrective actions in case they did not meet the levels defined in the SLAs, as well as providing advice, taking part into change advisory board (CAB) and other meetings, and making the yearly planning with regards to the ICT services provision.
- *Workplace Support* – this department was responsible for providing support with regards to the hardware and software equipment available at the workplaces of the users. This included the placing and installation of PCs, printers and other peripheral devices, installation of software available locally on the PC's, as well as troubleshooting of hardware and software problems related to the equipment available at the workplaces. Testing and acceptance of new hardware and/or software configurations of PCs and peripheral devices were also carried out here.
- *Application Management* – this department was responsible for the functional and technical management of the applications and databases used by the clients of the CSIP department. This included the daily monitoring and tuning of application parameters, analysing and solving application and database incidents and problems, designing, developing and implementing changes in the application code as a result of a request for new or changed functionality, and maintaining the documentation with regards to application architecture, infrastructure and functionality, as well as the evaluation, testing and implementation of proposed changes in the aplications and databases. Providing advice with regards to the functionality of the applications and databases and the associated service levels was also part of the tasks of the department.
- *Network Management* – this department was responsible for delivering network services to the clients of the CSIP department and for managing the implemented network and server infrastructure. This included the management of user accounts, carrying out small-

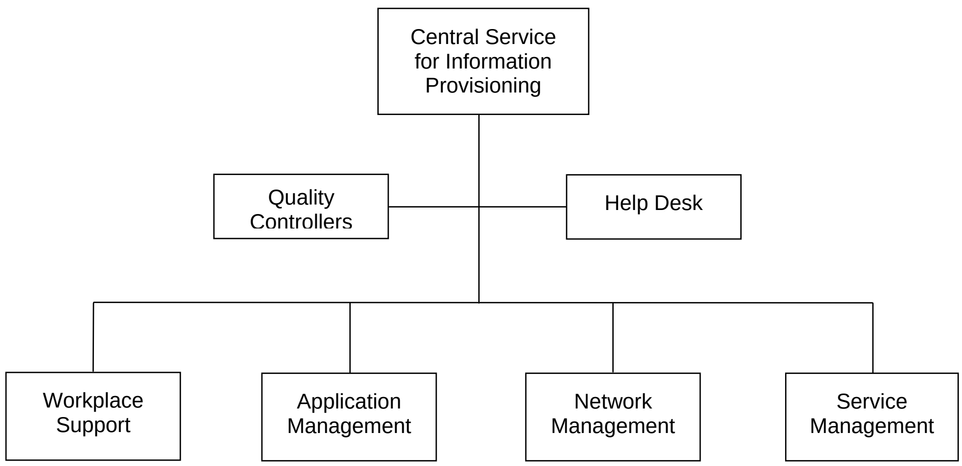

Figure 7.1: The ICT management departments of CSIP

scale workplace migrations, performing backups/restores of data, monitoring of servers, networks and databases and tuning system parameters in order to eliminate bottlenecks and improve performance, as well as carrying out preventive and corrective maintenance of the network and server infrastructure. Evaluation, testing and implementation of proposed changes to the network and server infrastructure were also carried out here. Advice with regard to network services and the associated service levels was also provided by the department.

- *Help Desk* – this department was responsible for providing a central contact point and first-line support with regards to all questions, incidents and requests related to the ICT infrastructure and applications. This included answering and registering client phone calls, resolving incidents for which a standard solution is available or sending the incidents to the appropriate department for resolution, checking incident resolution, informing users about a resolved incident, closing incidents, escalating incidents, as well as reporting with regards to the performance of the Help Desk. The Help Desk provided also a central contact point with regards to requests for routine changes, and was responsible for sending them to the appropriate support department, and informing the client about the progress of the change request.
- *Quality Controllers* – this department was responsible for keeping the continuity of the ICT services delivery by ensuring that the change management process within the department was carried out according to the defined time and quality criteria, and by verifying that the quality of new or changed hardware and/or software components met the predefined quality criteria before taking them into production. This included the registration and evaluation of change requests, the preparation and chairing of the Change Advisory Board (CAB) and processing and distributing its results, the monitoring and updating of the change management process as well as reporting with regards to change management issues.

The departments *Application Management*, *Network Management* and *Workplace Support* were also called *Technical Management* departments and will be referred to in this way in the rest of this chapter.

7.2.1 Step 1: Problem definition and demarcation of the study

The following sections provide information about the focus of the test case, the problem definition, the goals of the test case and the scope of the case.

Focus of the test case

In the course of the test case information about all departments within CSIP was gathered. However, due to time and resource constraints the focus of the case was limited to the Change Management process implemented within the CSIP department.

The goal of the Change Management process was to ensure that changes to the hardware and software infrastructure of the CSIP department were carried out in a controlled way so as to minimize the production disturbances resulting from them and their impact on the service levels. The process dealt mainly with *non-routine* changes, i.e., changes with (potentially) big impact on the service levels or changes for which no standard work instructions or procedures were available.

There were three main sources of such changes – the clients of the CSIP department, the Application Management departments and the Network Management department. The changes initiated by the client of the CSIP department concerned mostly requests for new functionality or extensions to the existing functionality, or requests for movement of people and/or equipment on a big scale as a result of an organizational restructuring. The changes initiated by the Application- and Network Management departments were mostly changes resulting from (potential) disturbances in the production environment, or changes resulting from a solved problem.

The Change Management process was carried out in the *Service Management* and *Quality Controllers* departments within CSIP. The *Service Management* department was responsible for coordinating changes initiated by clients and for evaluating the impact of implemented changes on the service levels. It was also responsible for informing the clients about changes that could lead to service deterioration. The *Quality Controllers* department was responsible for evaluating and authorizing all changes and assessing their implementation, as well as for enabling and facilitating the administration of the Change Management process.

The so-called *Request For Change* (RFC) played a central role in the Change Management process. For every (non-routine) change that had to be carried out an RFC was submitted in the RFC database of the CSIP department. In case the change was initiated by the client, the RFC was submitted by a *Service Coordinator* from the *Service Management* department described above. In case the change was initiated by the departments *Application Management* or *Network Management* the RFC was submitted by an authorized employee of these departments. The submitted RFCs and their impact and planning were discussed at the so-called Change Advisory Board (CAB). After that they were evaluated by an employee of the *Quality Controllers* department and in case the predefined requirements were met authorization for implementation was granted. After implementation an evaluation of the change was carried out by the *Quality Controllers* and the *Service Management* departments and the corresponding RFC was closed.

Problem definition

Due to the recent implementation of the Change Management process there were a number of issues that needed to be tackled in order to streamline the process and optimize its effectiveness and efficiency. These issues were related to the complexity of the organization and the fact that the departments and/or persons involved in the process were still not completely familiar with its structure and working. This resulted in a lack of clarity about the exact sequence of tasks that had to be carried out in order to react to a certain change request and produce the desired output (e.g., a change in the ICT infrastructure or the introduction of a new service or application) and the interfaces and interaction among the different departments and/or persons involved in the process, There was also a lack of insight about potential bottlenecks in the process, as well as about the time spent by the different people involved in the process on carrying out tasks and activities related to it.

Taking this into account, the problems addressed in the case were defined as follows:

- lack of clarity about the exact working of the process in practice, the sequence of tasks that had to be carried out and their input and output, as well as about the interaction among the different department and/or persons involved in the process;
- lack of clarity about the amount of time spent by the people involved in the process on carrying out tasks directly related to it.

Goals of the test case

In relation to the problems defined in the previous section, the goals of the test case were formulated as follows:

- Provide insight into the working of the Change Management process in practice by modelling the tasks carried out as part of it, their input and output, the departments where they were carried out and the people carrying them out, as well as the interaction among the persons and/or departments involved in the process;
- Provide an estimation of the time spent by the people involved in the processes on carrying out tasks directly related to it.

Scope of the test case

As explained above, the Change Management process was carried out in the *Service Management* and *Quality Controllers* departments within CSIP.Therefore, these departments and the tasks and activities carried out there were included explicitly in the simulation model. Next to this, other departments involved in the process (e.g., clients and the *Application Management* or *Network Management* departments) were also included in the model. However, the tasks and activities carried out there were modeled only to the extent necessary to provide insight into, and capture the working of the Change Management process.

Similarly to the case described in the previous chapter, this case was focused on the tasks carried out by the people at the operational level. This included submitting RFCs in the RFC database and their subsequent evaluation and authorisation, as well as the assessment of their implementation. Development activities necessary for building services and/or applications as a result of a change request were left out of consideration, as well as management activities related to the work of the different departments involved in the Change management process, except for the cases where the modelling of these activities was necessary for capturing and representing specific situations, e.g., urgent changes as a result of a serious production disturbance.

Due to the recent implementation of the Change Management process there were no sufficient historical data about the different parameters of the process, e.g., frequency of receiving of change requests or the duration of tasks and/or activities carried out as part of the process. Therefore the gathering of data necessary to build the model was restricted to questionnaires and interviews with people involved in the process. These data were considered representative and sufficient for achieving the purposes of the test case.

Data about activities not directly related to the core activities of the different departments and/or persons (e.g., vacation, sickness, meetings, coffee breaks, etc.) were used in the model based on assumptions about the average time spent by the personnel of the department on such activities and their frequency.

7.2.2 Step 2: Data collection

In this sub-section the data gathered during the test case and used for building the simulation model of the Change Management process implemented within the CSIP department are presented. In line with the approach described in chapter 5, a distinction is made between two different kinds of data: *structural process data* described in sub-section 7.3.2.1 and *quantitative process data* described in sub-section 7.3.2.2.

7.2.2.1 Structural Process Data

The structural data comprise information about the concrete implementation of the generic structural elements described in chapter 3. In line with this, in the next sections information is provided about the *information objects*, the *workplaces, tasks and activities* and the *equipment* used in the Change Management process.

Information objects

Three basic information objects were identified: These were *Request for Change, Implementation Request* and *Implementation Information.* A description of these information objects and their characteristics is given below.

The information object *Request for Change* represented the RFCs used to store information about the changes that had to be carried out. It was characterized by its *owner*, its *priority,* its *implementation date* and its *status*. The *owner* of the RFC was the person who submitted it and who was responsible for providing all information necessary for its evaluation and implementation. The *priority* of the RFC indicated the speed with which the change it referred to had to be implemented. The *implementation date* was the date on which the change the RFC referred to had to be implemented. The *status* represented the state of the RFC and took the values *initial, authorized, rejected, implemented* and *closed*.

The information object *Implementation Request* represented the request sent to a department responsible for implementing an authorized change. It was characterized by its *priority,* its *implementation date*, the *RFC* it referred to and its *status*. The role of the first two characteristics was similar to the role of the corresponding characteristics of the *Request for Change* information object. The *RFC* contained the identifier of the RFC that had to be implemented. The *status* represented the state of the implementation request and took the values *open* and *executed.*

The information object *Implementation Information* represented the information provided by the person responsible for carrying out an implementation request to the people controlling the corresponding RFC. The main characteristic of this object were the *RFC* it referred to, the *execution date* of the implementation request and information about whether the implementation was *successful* or not.

Workplaces, Tasks and Activities

Two types of workplaces were distinguished within the Change Management process. These were the *Service Coordinator* and *Quality Controller*. These workplaces, the tasks carried out there and their constituent activities are described in the following sections.

Service Coordinator

The *Service Coordinator* served as a central contact point for the clients of the CSIP department and was responsible for two aspects of the delivery of ICT services: *service level management* and *service request management*. The *service level management* included negotiating the Service Level Agreements (SLAs), monitoring the actual service levels, comparing them to the levels defined in the SLAs and taking corrective action where necessary. The *service request management* included determining the information needs of the clients, facilitating them with regard to defining requests for new and changed services, planning and coordinating the development and implementation of a (new and changed) service and delivering the service to the clients. Next to this, the *Service Coordinator* maintained the relationship with the client, provided advice with regard to the delivery of ICT services and took part in different meetings and consultations.

In relation to this, the tasks carried out by the *Service Coordinator* and their constituent activities were defined as follows:

- *Negotiate SLA's* – this task comprised of determining the service levels needed by the clients, assessing their feasibility by consulting the managers of the different departments within CSIP and recording the service levels into formal service level agreements (SLA's). The following activities were defined for this task:
  - *Discuss required service levels with clients* – consisted of discussing with and advising the clients with regard to ICT services and determining the desired parameters (service levels) of these services, such as availability, response time and recovery time.
  - *Discuss service levels with department managers* – consisted of discussing the service levels desired by the clients with the managers of the different departments within CSIP in order to determine their feasibility and costs. This and the previuous activity were carried out iteratively until an agreement was reached.
  - *Register agreed service levels* – when an agreement was reached the service levels were registered in service level agreements (SLA's) which after that served as a formal agreement between the users and suppliers of ICT services.
- *Manage service levels* – the purpose of this task was to ensure that that the actual service levels corresponded to the agreed service levels and take corrective action otherwise. The task consisted of the following activities:
  - *Compare actual and agreed service levels* – this activity consisted of monitoring on a regular basis of the actual service levels based on data from the Help Desk and the Application Management, Network Management and Workplace Support departments within CSIP. The actual service levels were then compared to the service levels defined in the SLA's in order to determine the degree to which they corresponded to each other and identify discrepancies.

  - *Solve service level issues* - this activity comprised the actions carried out in order to resolve service level issues identified in the previous activity. This included discussing the issues with the managers of the different departments within CSIP, providing the necessary resources and monitoring their resolution
  - *Discuss actual service levels with client* – this activity consisted of discussing the achieved service levels with the clients, providing information about the degree to which they corresponded to the service levels defined in the SLA’s and discussing the issues encountered during services production.

- *Formulate service request* – the purpose of this task was the formulation of requests for new or changed services. This included determining the information needs of the client, formulating the service request, discussing it with department managers in order to determine its feasibility and with a project leader in order to determine the time necessary to realize it. In connection to this, the following activities were defined for this task:
  - *Determine client needs* – consisted of discussing the information needs of the clients, advising them about the way in which these needs could be met by changing existing ICT services or introducing new ones.
  - *Formulate service request* – after determining the needs of the client, a service request was formulated. This request contained information about the required new or changed functionality as well as other relevant data, e.g., the client/department submitting the request, purposes for which the service will be used and the required availability and/or security.
  - *Discuss service request with department managers* – after a service request was formulated, it was discussed with the managers of the departments that would be involved in providing the service. The purpose of this was to determine its feasibility and the expected costs. If necessary, the service request was adjusted in consultation with the client.
  - *Discuss service request with project leader* – in case a service request was considered feasible, it was discussed with a project leader in order to determine the resources and time necessary to implement it.
- *Realise service request* – the purpose of this task was to ensure the realization of the service requests of the clients by monitoring and solving problems in the course of the development and implementation of the new or changed services, delivering the end-product to the client and making an assessment about the implemented request. The task consisted of the following activities:
  - *Monitor service development progress* – this activity consisted of monitoring on a regular basis the development of the required service in order to ensure that it was taking place according to the agreed planning, and providing information to the client about the progress.
  - *Solve service development problems* – the purpose of this activity was to resolve problems encountered during the development of a service. This included providing additional resources and/or expertise and escalating the problems in order to ensure that they receive the necessary attention and priority.
  - *Submit RFC* – when the required service was developed and tested an RFC was submitted for implementing it into production. The RFC contained the information necessary to carry out the implementation and was used to monitor its progres.

- *Monitor implementation* - this activity consisted of monitoring on a regular basis the progress of the implementation of the service request and ensuring that it took place according to the agreed planning.

- *Assess request implementation* – consisted of carrying out an assessment of the implementation of the service request. This included the implementation timeline and costs, the accuracy of the implementation plan and the disturbances to the service levels caused by the implementation

- *Deliver end-product to client* – the purpose of this task was to formally deliver the end-product to the client after realising the service request and assessing its implementation.

- *Maintain client relationships* – the purpose of this task was to maintain the relationships with the clients and stay up-to-date with regard to their business processes, their information needs and the degree to which they were satisfied with the received ICT services. The task consisted of the following activities:

    - *Read relevant client information* – this activity consisted of reading relevant information about the clients in order to get acquainted with or follow recent developments in their business processes. The information included descriptions of the client organizations, business strategy documents and yearly plans.

    - *Visit clients* – this activity consisted of visiting the clients in order to get a direct impression and (possibly) experience with the way in which the business processes were carried out.

    - *Discuss client information needs* – this activity consisted of discussing the ways in which the use of ICT could lead to improvements in the business processes of the clients.

    - *Solve ad-hoc issues* – this activity consisted of solving ad-hoc client complaints and problems with regard to the quality of the delivered ICT services.

- *Planning* – the purpose of this task was to assist the client with planning service requests. This included the formulation of the so-called *templates* which contained, among other things, information about planned service requests and the dates for starting and finishing their formulation, development and implementation. The task consisted of the following activities:

    - *Formulate templates with client* – consisted of advising the clients and formulating (together with them) the templates about the planned service requests.

    - *Discuss templates with department managers* – consisted of discussing the feasibility of the formulated templates with the managers of the departments involved in developing or implementing the service requests and making changes to the templates in consultation with the clients.

- *Meetings and administration* –this task comprised the different meetings and consultations attended by the Service Coordinator and the administrative matters he/she had to handle. The task consisted of the following activities:

    - *Service Management Team (SMT) meeting* – this activity consisted of holding a meeting on a regular basis with the other Service Coordinators within the Service Management department of CSIP.

    - *Operational consultations* – this activity consisted of holding a consultation on a regular basis for discussing operational issues within the CSIP department.

- *Consultations with department managers* - this activity consisted of holding a consultation on a regular basis with the managers of the different departments within CSIP for discussing issues related to the organization of the ICT services production.
- *Help Desk consultations* - this activity consisted of holding a consultation on a regular basis with employees of the Help Desk department with regard to current or expected problems in the ICT services provision.
- *Change advisory board* - this activity consisted of holding a meeting on a regular basis with the other Service Coordinators and the Quality Controllers in order to discuss the content, prioritizing, evaluation and implementation planning of current RFC's.
- *Make/update action list* – consisted of making or updating a list of actions necessary for formulating, developing and implementing a service request.

Quality Controller

The main role of the *Quality Controller* was to protect the production environment against disturbances caused by changes that did not meet the predefined quality criteria with regard to development, testing or implementation. In this way, the *Quality Controller* was responsible for evaluating all changes for which an RFC was submitted and ensuring that they were properly developed, tested and documented and that all the resources necessary for their implementation were available. Next to this, the *Quality Controller* was responsible for the preparation and chairing of the Change Advisory Board, maintenance of the RFC database used at the CSIP department, process evaluation, providing instruction and reporting with regard to the Change Management process.

In relation to this, the tasks carried out by the *Quality Controller* and their constituent activities were defined as follows:

- ❑ *Study RFC's* – this task comprised the handling and evaluation of RFC submitted in the RFC database. It consisted of the following activities:
  - *Register RFC* – this activity comprised the initial administration of the RFC's submitted in the RFC database. This included registering the person/department where the RFC came from, the priority of the RFC and the change that had to be implemented.
  - *Study implementation plan RFC* – included studying the date or period for which the implementation of the RFC was planned. For complex RFC's consisting of several implementations and influencing multiple components a special implementation plan was made which included the dates of the different implementations and their interdependencies.
- ❑ *Evaluate RFC* – consisted of evaluating an RFC based on the related development documentation, test plans and test reports, availability of the necessary hardware, software and human resources and contingency planning/fall-back scenario.
- ❑ *Evaluate routine changes* – this activity was carried out in case the RFC concerned a routine change, for which a work instruction was available. No special consultations with the implementing department were necessary in this case.
- ❑ *Consult implementing department* – before authorising an RFC the *Quality Controller* consulted the department responsible for its implementation in order to verify that the

conditions for implementation were met. However, this activity was carried out only for small changes. The consultation for big changes took place during the CAB.

- *Change Advisory Board (CAB)* – the purpose of this this task was the preparation and chairing of the Change Advisory Board (CAB) and the processing and communicating its results. It consisted of the following activities:
  - *Prepare Change Advisory Board* – this activity comprised the preparation of the agenda for the CAB, the list of RFC's waiting for authorisation and the plannning for their implementation, as well as the list of issues that had to be discussed.
  - *Chair Change Advisory Board* – consisted of chairing the Change Advisory Board and ensuring that it followed the predefined agenda.
  - *Process results Change Advisory Board* – consisted of processing the results of the CAB by documenting the reached agreements and the actions defined for the different CAB members, and sending them to the interested parties.
- *Provide instructions* – consisted of providing instructions to interested parties (e.g., employees responsible for submitting or implementing RFC's) with regard to the rules and procedures used as part of the Change Management process.
- *Evaluate RFC implementation* – consisted of evaluating the implementation of the RFC's taken into production since the last report. This included evaluating parameters like date and time of implementation (as compared to the ones specified in the implementation plan), accuracy of implementation instructions and production disturbances during implementation.
- *Prepare Change Management report* – consisted of prepairing the Change Management report which included the implementation evaluation obtained from the previous activity, information about the open, processed and authorised RFC's as well as the planning for the coming period.
- *Change Management database (CMDB) maintenance* – consisted of maintaining the Change Management database used within the CSIP department. This included improving the existing functionality of the database and adding new or changed functionality as a result of changes in the Change Management process.
- *Evaluate project plans* – the purpose of this task was to get acquainted with and provide advice about the planning of projects dealing with considerable changes in the technical or application infrastructure of the CSIP department.
- *Meetings* – this task comprised the meetings and consultations (next to the Change Advisory Board) attended by the Quality Controller. It consisted of the following two activities:
  - *Service Management Team (SMT) meeting* – consisted of attending a meeting of the so-called Service Management Team which included the people responsible for coordinating the ICT services production within CSIP.
  - *Process consultations* – consisted of attending a meeting of the people involved in the Change Management process and holding consultations about the functioning and performance of the process, (possible) issues and bottlenecks and the way in which they could be improved.

Equipment

Different kinds of hardware and software equipment were used in the Change Management process. However, two kinds of equipment were critically important for its effectiveness and efficiency. These were the Change Management Database used at the CSIP department and the equipment available at the individual workplaces in the department. The following paragraphs provide more information about these kinds of equipment, taking into account the goals and the specific requirements of the test case.

The Change Management Database was based on Applix – a customizable software platform for planning and managing business processes. It was placed on a central server and special measures were taken to ensure its high availability. The database had interfaces to all persons and/or departments involved in the Change Management process and provided means for creating and submitting an RFC, assigning it to a specific department, tracking its handling, changing its status, as well as for archiving RFC's and reopening them at a later time if necessary. The RFC records in the database contained all relevant information about a change that had to be implemented in production. This included description of the change, its priority, the affected hardware and/or software components, the necessary resources, and documentation about the design, development and testing of the change (as far as applicable). The CMDB was a core tool used in the Change Management process and its availability and performance were of critical importance for handling the RFC's in a timely, effective and efficient manner.

The workplaces of the people involved in the Change Management process were equipped with a Microsoft Windows NT® based personal computer and a telephone. The personal computer offered the interfaces and emulators necessary to realize the access to the Change Management database and other tools, as well as other applications as e-mail clients, Microsoft Office and Inter/Intranet.

7.2.2.2 Quantitative Process Data

Next to the structural data, quantitative data about the Change Management process were also gathered. These data contained information about the duration of the different activities carried out as part of the process and the frequency with which they were carried out. This is presented in the following sections.

As explained in the previous chapter, we have chosen to gather data about the duration of activities rather than the duration of tasks because the duration of an activity is relatively stable and we can obtain an estimation of it, while the duration of a task depends on the processed information object and the exact activities that have to be carried out.

The data about the duration of the different activities* carried out at the workplaces involved in the Change Management process were gathered by using questionnaires and interviews. For the duration of each activity a minimum, average and maximum duration were specified,

* As explained in chapter 4, a task consists of one or more activities. In case a task consists of one activity, the activity carries the name of the task.

as well as a standard deviation for each duration. However, it was concluded that the actual duration of the different activities was not distributed uniformly among the minimum, average and maximum values. Therefore, for each of these values an estimation was made about the percentage of time when it corresponded to the actual duration. The gathered data were estimated to cover 92% of the actual situation.

The durations and frequency of the activities carried out at the *Service Coordinator* workplace are given in table 7.1. The data in the table represent average values based on data obtained from interviews with people involved in the process over a period of four months. The durations are given in minutes per occurrence of the activity, while the frequency is given as (average) number of occurrences for a specified time period (week or month). For example, the data about the duration of the first activity listed in the table should be read as: 30% of the time the activity has a duration of 240 minutes with a deviation of 30 minutes, 40% of the time the activity has a duration of 360 minutes with a deviation of 30 minutes, 30% of the time the activity has a duration of 480 minutes with a deviation of 60 minutes, the activity is carried out once per month.

Activity	*Min.*	*Avg.*	*Max.*	*Frequency*
Discuss required service levels with clients	240 (30) –30%	360 (30) – 40%	480 (60) – 30%	1 p/m
Discuss service levels with department managers	180 (30) – 25%	240 (30) – 50%	360 (60) – 25%	1 p/m
Register agreed service levels	60 (10) – 20%	75 (10) -60%	90 (10) – 20%	1 p/m
Compare actual and agreed service levels	30 (10) – 20%	60 (10) – 60%	90 (15) – 20%	1 p/m
Solve service level issues	30 (10) – 15%	60 (15) – 60%	90 (15) – 25%	1 p/w
Discuss actual service levels with client	45 (10) – 30%	60 (10) – 40%	90 (15) – 30%	1 p/m
Determine client needs	180 (30) – 15%	300 (45) – 70%	420 (60) – 15%	1 p/w
Formulate service request	90 (15) – 20%	120 (15) - 60%	150 (15) – 20%	1 p/w
Discuss service request with department managers	45 (10) – 20%	60 (10) – 60%	90 (15) – 20%	1 p/w
Discuss service request with project leader	90 (15) – 10%	120 (15) – 70%	180 (30) – 20%	1 p/w
Monitor service development progress	30 (5) – 30%	45 (5) – 40%	60 (5) – 30%	1 p/w
Solve service development problems	30 (5) – 15%	45 (5) – 55%	60 (10) – 30%	1 p/w
Submit RFC	10 (2) – 10%	15 (2) – 80%	20 (5) – 10%	1 p/w

Table 7.1: Duration of the activities of the *Service Coordinator* workplace

Monitor implementation	10 (5) – 20%	20 (5) – 50%	30 (5) – 30%	2 p/w
Deliver end-product to client	30 (10) – 10%	60 (10) – 50%	90 (15) – 40%	1 p/w
Assess request implementation	30 (5) – 20%	45 (5) – 70%	60 (10) – 10%	1 p/w
Read relevant client information	60 (10) – 20%	90 (15) – 50%	120 (15) – 30%	1 p/w
Visit clients	45 (5) – 10%	60 (5) – 20%	75 (10) – 70%	1 p/w
Discuss client information needs	90 (10) – 30%	120 (15) – 40%	150 (15) – 30%	1 p/w
Solve ad-hoc issues	120 (10) – 40%	150 (15) – 40%	200 (15) – 20%	1 p/w
Formulate templates with client	360 (60) – 10%	600 (90) – 80%	840 (90) – 10%	1 p/m
Discuss templates with department managers	60 (15) – 30%	90 (15) – 40%	120 (15) – 30%	1 p/m
Service Management Team (SMT) meeting	–	120 (15) – 100%	–	2 p/m
Operational consultations	–	60 (15) – 100%	–	1 p/w
Consultations with department managers	–	60 (15) – 100%	–	1 p/w
Help Desk consultations	90 (15) – 10%	120 (15) – 60%	150 (15) – 30%	1 p/m
Change advisory board	60 (15) – 10%	90 (15) – 80%	120 (15) – 10%	1 p/w
Make/update action list	60 (5) – 30%	90 (5) – 50%	120 (15) – 20%	1 p/w

Table 7.1 *(Continued)*

The durations and frequency of the activities carried out at the *Quality Controller* workplace are given in table 7.2. The data in the table represent average values based on data obtained from interviews with people involved in the process over a period of four months. The durations are given in minutes per occurrence of the activity, while the frequency is given as (average) number of occurrences for a specified time period (week or month).

Activity	*Min.*	*Avg.*	*Max.*	*Frequency*
Register RFC	–	15 (5) – 100%	–	10 p/w
Study implementation plan RFC	15 (5) – 65%	30 (10) – 25%	60 (15) – 10%	10 p/w
Evaluate RFC	15 (5) – 65%	30 (10) -40%	120 (15) – 5%	10 p/w
Evaluate routine changes	10 (5) – 35%	15 (5) – 60%	20 (5) – 5%	10 p/m

Table 7.2: Duration of the activities of the Quality Controller workplace

Consult implementing department	15 (5) – 60%	30 (10) – 35%	120 (30) – 5%	10 p/w
Prepare CAB	10 (5) – 10%	20 (5) – 80%	60 (15) – 10%	1 p/w
Chair CAB	60 (15) – 30%	90 (15) – 60%	120 (15) – 10%	1 p/w
Process results CAB	30 (5) – 25%	60 (15) - 70%	120 (30) – 5%	1 p/w
Provide instructions	–	30 (10) – 100%	–	1 p/m
Evaluate RFC implementation	–	20 (10) – 100%	–	10 p/w
Prepare Change Management report	120 (30) – 40%	240 (30) – 40%	480 (60) – 30%	1 p/m
CMDB maintenance	120 (30) – 30%	240 (60) – 40%	480 (60) – 30%	1 p/m
Evaluate project plans	15 (5) – 20%	30 (10) – 70%	120 (30) – 10%	1 p/m
Service Management Team (SMT) meeting	–	120 (15) – 100%	–	2 p/m
Process consultations	–	60 (15) – 100%	–	2 p/m

Table 7.2 *(Continued)*

7.2.3 Step 3: Conceptual model development

The development of the conceptual model of the functioning of the Change Management process consisted of specifying the classes that were used to represent the identified process elements and defining the relationships of these classes. It also included a mapping of the process logic that comprised of the communication model, process model and workplace model described in chapter 5. In line with this, in the following sections information is provided about the *classes and their relationships,* as well as about the *process logic of the Change Management process.*

Classes and their Relationships

Based on the structural data presented in sub-section 7.2.2.1 the classes that were used to build the simulation model of the Change Management process were specified. These classes were divided into three main categories: classes representing information objects*, classes representing workplaces and classes representing equipment

As explained above, three basic information objects were identified in the work of the Change Management process: These were the *Request for Change*, *Implementation Request* and *Implementation Information.* In order to represent these information objects, the *Information Object* class needed to be extended to include additional attributes. Therefore, based on this

* The term *information object* is used here to denote the corresponding process element defined in chapter 4, and should not be confused with the term *object* used to denote an instance of an *object class* in the object-oriented terminology.

class, for each of the information objects a new class was defined which added the specific attributes necessary to represent them. This is depicted in fig. 7.2.

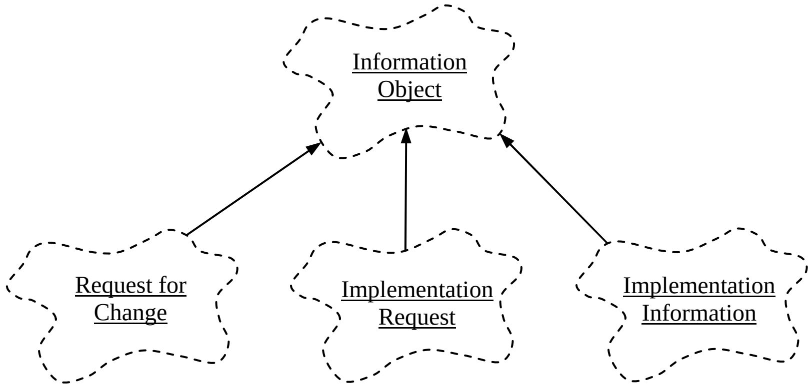

Figure 7.2: The three new *Information Object* classes

The specifications of the three new classes and the additional attributes they include are given in fig. 7.3.

Object class *Request for Change*

Inherits from

Information Object

Attributes

Owner

Priority

Implementation date

Status

Object class *Implementation Request*

Inherits from

Information Object

Attributes

RFC

Priority

Implementation date

Status

Object class *Implementation Information*

Inherits from

Information Object

Attributes

RFC

Execution date

Successful

Figure 7.3: The specification of the three new *Information Object* classes

In order to represent the workplaces of the Change Management process two new classes had to be defined. These classes corresponded to the workplaces *Service Coordinator* and *Quality Controller* described in the previous section. The classes inherited the structure, attributes and methods of the *Workplace* class described in chapter 4 and provided a concrete definition of its *Tasks* attribute. The two new classes are depicted in fig. 7.4.

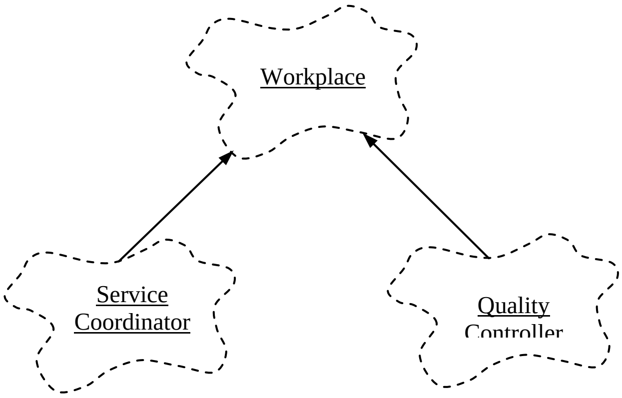

Figure 7.4: The two new *Workplace* classes

The definition of the *Tasks* attribute for each of the classes corresponded exactly to the tasks for the respective workplace defined in sub-section 7.3.2.1. Therefore, no further specification of the classes is provided here.

The *Change Management Database* described in sub-section 7.3.2.1 was included explicitly in the simulation model. In order to represent it a new class was defined. This class inherited the structure, attributes and methods of the *Equipment* class described in chapter 4, however, two new methods were added to it in order to represent the logic used to process information items. The new class is depicted in fig. 7.5.

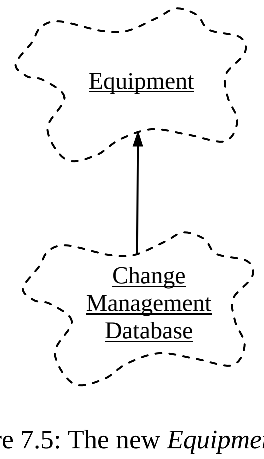

Figure 7.5: The new *Equipment* class

The specification of the new class and the methods added to it is depicted in fig. 7.6. As it can be seen from the figure, a *Process RFC* method was added to the class. This method

Object class *Change Management Database*

Inherits from

Equipment

Methods

Process RFC ()

Process Data Request ()

Figure 7.6: The specification of the new *Equipment* class

represented the logic necessary for receiving RFC's, assigning them to the proper IT worker and storing changes in their status. A *Process Data Request* method was also added representing the logic necessary for processing request for data about the status of RFC's.

The interactions of the object classes representing the workplaces and equipment of the Change Management process are captured in the interaction diagram depicted in fig. 7.7. The interactions are based on the description of the workplaces and equipment provided in sub-section 7.3.2.1. The information objects exchanged in the interactions are not explicitly included in the figure. They are captured in the models of the process logic presented below.

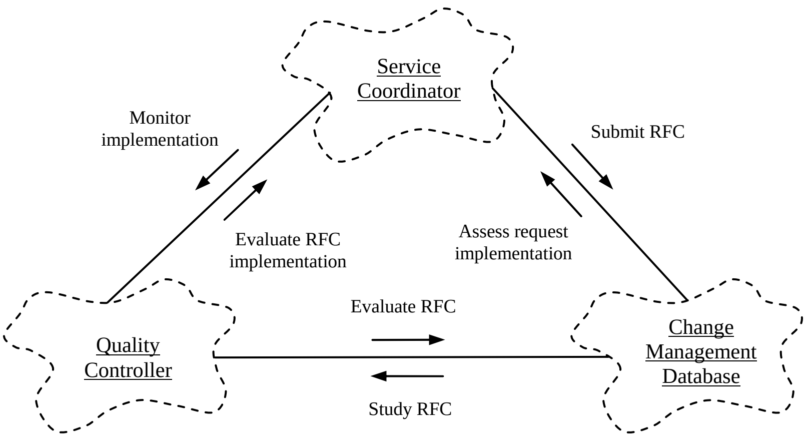

Figure 7.7: The interaction diagram of the Change Management process

Process Logic of the Change Management Process

The process logic of the Change Management process was captured using the *communication model*, the *process model* and the *workplace model* presented in the previous chapter.

The *communication model* of the Change Management process is depicted in fig. 7.8. It captured the exchange of information that took place as part of the work of the Change Management process and comprised of the workplaces and the equipment included in the conceptual model of the process, as well as the information objects exchanged in their interaction. The model also included the external parties which provided input to or received output from the process. These were the *Clients* the *Technical Management* departments within CSIP. The *Clients* submitted requests for new or changed services and received and accepted the end-product. The *Technical Management* departments played a two-fold role in the process. They, on the one hand, submitted RFC's for solving (potential) production disturbances and problems and, on the other hand, implemented the changes requested in the different RFC's (submitted both by the departments themselves and by the Service Coordinators as a result of a client service request). An explanation of the abbreviations used to denote the names of the information objects is provided in the legend included in the figure. The communication model formed the basis for defining the user view of the simulation model of the ICT Help Desk described later in this chapter.

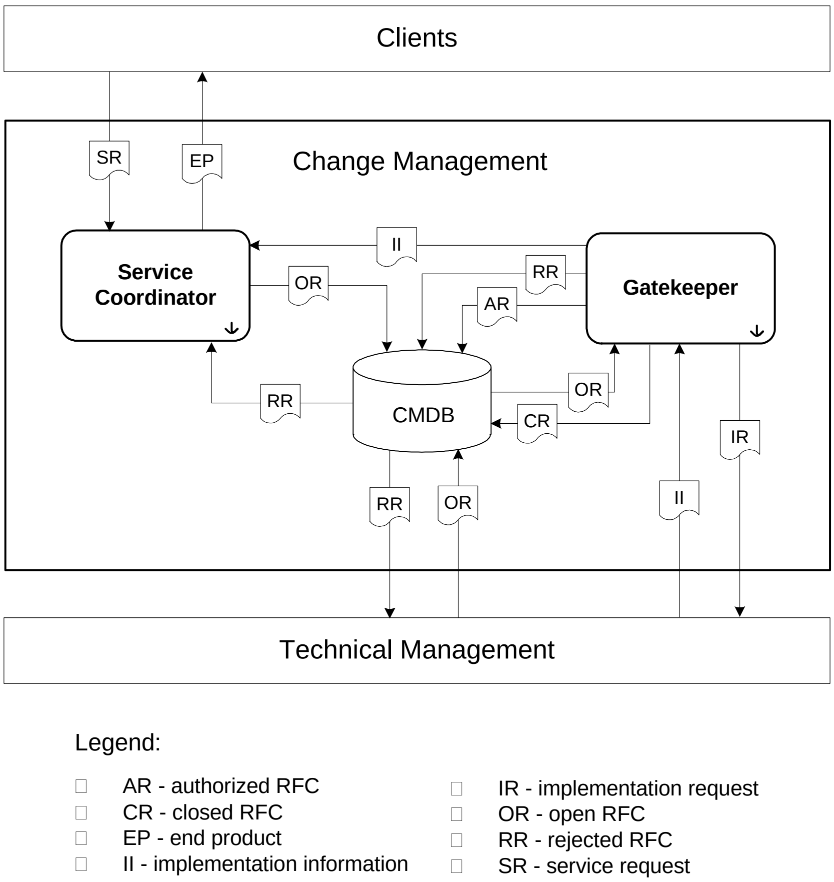

Figure 7.8: The communication model of the Change Management process

The *process model* of the Change Management process is depicted in fig. 7.9. The model captures the tasks carried out as part of the process, the workplaces at which they were carried out, the sequence in which they were carried out and the conditions governing this sequence. The information objects serving as an input to or output of the process and the different tasks were also represented in the model. The external parties (*Clients* and the *Technical*

Management departments) providing input to or receiving output from the process were also included in the model. The Change Management Board (CAB) was also included in the model. However, it was taken into account only to the extent to which it served to discuss important changes with (possibly) big impact and inform the interested parties about the (possible) consequences on the service levels, without going into further detail about its functioning. Therefore, it was included in the model as an external block which implicitly included the related tasks of the Quality Controller and the Service Coordinator workplaces.

The process model was built using the notation described in the previous chapter. The abbreviations used to denote the names of the information objects are the same as the ones used in fig. 7.8.

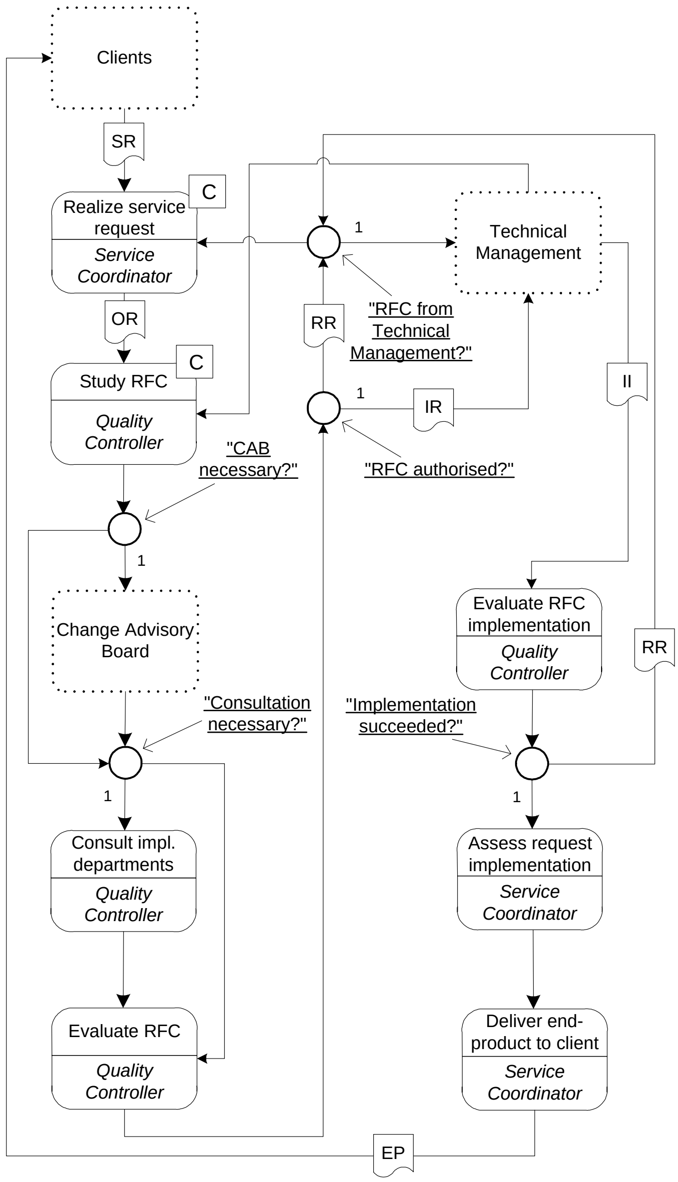

Figure 7.9: The process model of the Change Management process

The *workplace model* was used to capture the tasks and activities carried out at the individual workplaces involved in the Change Management process, the logic and conditions governing their execution, the used equipment as well as the exchanged information objects. The external parties providing input to or receiving output from a workplace were also included in the respective workplace model. The developed workplace models of the *Quality Controller* and the *Service Coordinator* are depicted in figures 7.10 and 7.11 respectively. It should be noted that only tasks directly related to the Change Management process were included in the models.

The workplace models were built using the notation described in the previous chapter. The abbreviations used to denote the names of the information objects are the same as the ones used in fig. 7.8.

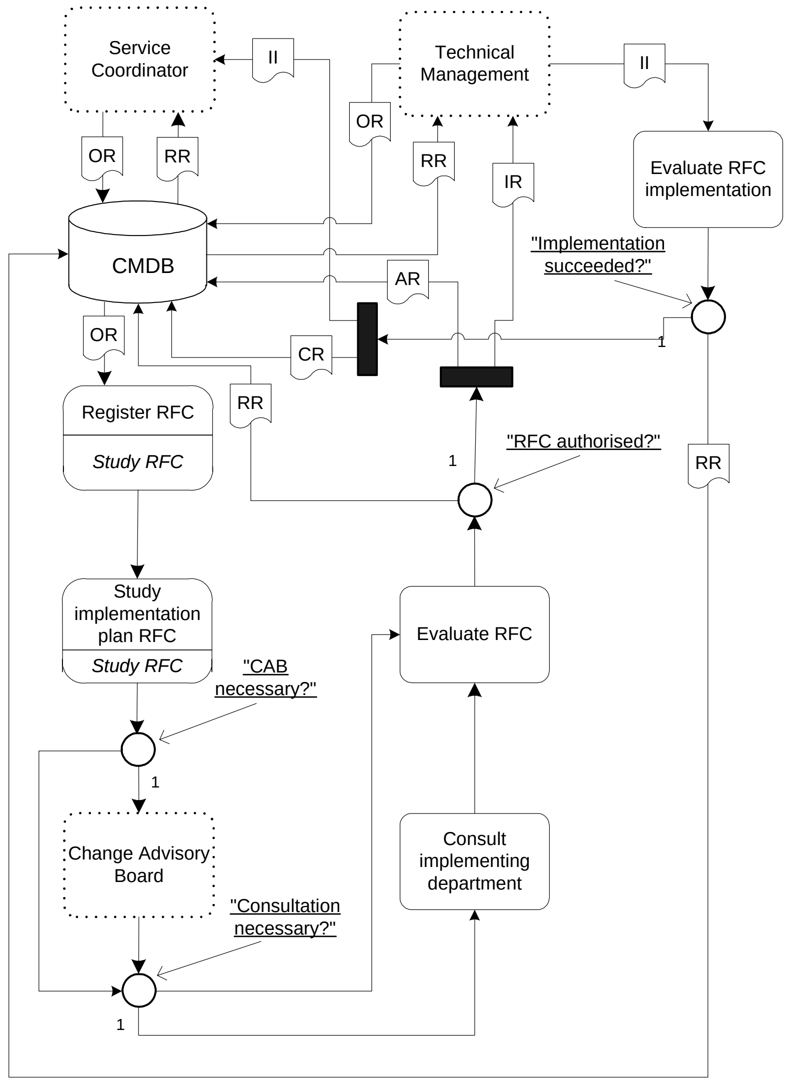

Figure 7.10: The workplace model of the *Quality Controller*

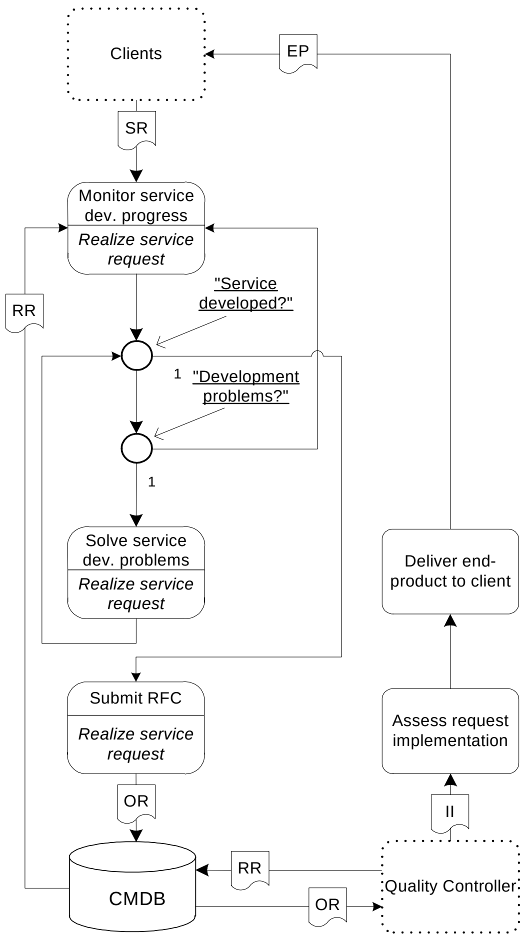

Figure 7.11: The workplace model of the *Service Coordinator*

7.2.4 Step 4: Building the simulation model

Based on the conceptual model described in the previous section and the gathered structural and quantitative process data the simulation model of the Change Management process was built using the objects of the object class library for ICT management simulation described in chapter 4. This included building the model structure and logic, filling in the model data, and the verification and validation of the model. This is described in the next sections.

Building the Model Structure and Logic

The structure of the model was build using the information objects, workplaces and equipment described in the previous section. The model included six IT workers working at the *Service Coordinator* workplace and two IT workers working at the *Quality Controller* workplace. The model also included one equipment item representing the *Change Management Database* due to the key role they played in the process. The *clients* submitting requests for new or change services, the *Technical Management* departments submitting RFC's and implementing changes, as well as the *Change Advisory Board* were represented in the model only to the extent necessary to capture their impact on the work of the Change Management process.

In order to achieve a clear visualization of the information objects exchanged and processed in the model icons with different shapes and/or color were used to represent the different types of objects and their states. In this way, different icons were used to represent the service requests, the RFC's, the implementation requests and the implementation information. In order to distinguish among the priorities of these information objects, different colors were used for the different priorities of the objects.

Additional logic was built into the model in order to represent the attending of the Change Advisory Board (CAB) by the different IT workers. This logic took into account the absence of the workers from their workplaces during the CAB, however, it included the possibility to interrupt the CAB and let a worker perform other activities in case of an occurrence of a high-priority event.

Taking into account the goals of the test case, the main performance indicator built into the model was the percentage of time spent by the IT workers on tasks and activities directly related to the Change Management process. In order to achieve realistic data about this indicator tasks and activities carried out by the workers and not directly related to the process were also included in the model, however, this was done only to the extent necessary to represent their influence on the sequence and overall duration of the ones directly related to the Change Management process.

The user view of the developed simulation model of the work of the Change Management process is depicted in fig. 7.12.

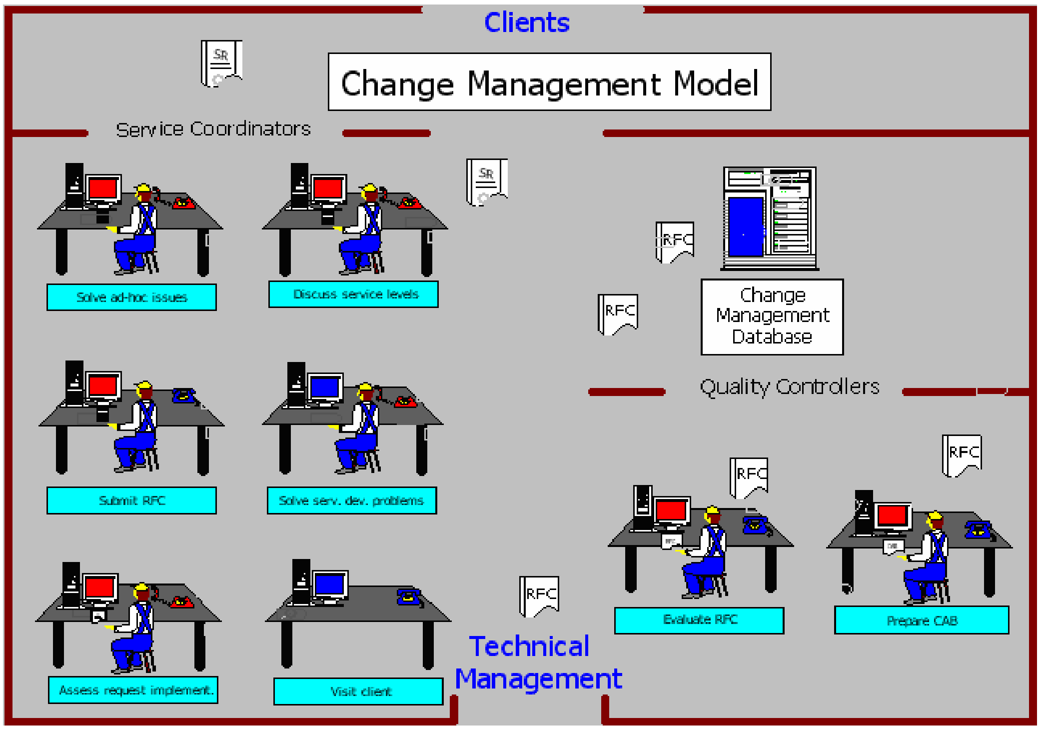

Figure 7.12: The user view of the Change Management process model

Filling in Model Data

The data filled into the model were based on the data presented in sub-section 7.2.2.2. A distinction was made among data about the frequency of arrival of client service requests, data about the frequency of submitting RFC's by the Service Coordinators and the Technical Management departments, and data about processing times at the different workplaces and the different courses of action taken.

The data about the frequency of arrival of client service requests and the frequency of submitting RFC's by the Service Coordinators and the Technical Management departments were based on the data about the frequency of the tasks carried out in order to process them. This was done due to the fact that no historical data were available with regard to these frequencies. A random number generator with a *normal distribution* was used to generate the arrivals with the value provided in the table used as a mean value and a standard deviation of 20% of this value. A different generator was defined for the arrival of client service requests and the resulting RFC's submitted by the Service Coordinators on the one hand, and the arrival of RFC's submitted by the Technical Management departments, on the other. The used time units in the model corresponded to one second in the real-life situation in order to improve the visualization and the possibilities for fine-tuning the model.

The data about the processing times at the different workplaces were based on the activity duration data given in tables 7.1 and 7.2. A separate random number generator using a *normal distribution* was used to generate the processing times for each activity. This was done taking into account the minimum, average and maximum value provided for the durations, the corresponding standard deviations and the percentage indicating the probability of occurrence of the duration.

A distinction was made between activities carried out on a regular basis and activities carried out on an ad-hoc basis. The activities carried out on a regular basis (e.g., the different consultations) were carried out according to a predefined schedule and the data gathered about their frequency were based on this schedule. The activities carried out on an ad-hoc basis were carried out in order to react to the occurrence of an event triggering them (e.g., the arrival of a service request or client problem), and the data gathered about their frequency were an average estimation provided by the people carrying them out.

In order to obtain a realistic picture of the overall workload on the different workplaces involved in the Change Management process data about tasks and activities not directly related to the model were also included into the model. However, they were represented only to the extent necessary to reflect their influence on the workload on the workplaces and the execution and overall duration of the tasks and activities directly related to the process.

Model Verification

Structured walkthroughs of the model logic, tracing model operation, special modeling conditions and observation of certain model parameters were used to verify the functioning of the simulation model.

Structured walkthroughs of the model logic were carried out with the participation of persons working at the workplaces described above. The scope of the model and the made assumptions were described and the modeling of the different parts of the work of the Change Management process (e.g., handling of client requests, handling of RFC's or the implementation of changes) was explained, and the work of (relevant parts of) the simulation model was demonstrated.

Tracing of the model operation was used to ensure that it corresponded to the logic captured in the communication, process and workplace models described above. The tracing was carried out by executing the model step by step and visualizing the active information object and the active module of the model logic, as well as by checking the values of information object attributes and model variables to verify their correct assignment.

Special modeling conditions and observation of model parameters were also used to verify the model. This comprised the generation of a single information object of a certain type and following its processing through the model, as well as generating high workloads for the different workplaces in the model in order to ensure their correct functioning. Model parameters like the number of information objects in certain queues of the model and their average waiting time, or the percentage of time spent on the different tasks and activities defined for a specific workplace were observed in order to ensure the model was functioning as expected.

Model Validation

The model was validated using face validation with subject matter experts and replicative validation of the model output.

The face validation with subject matter experts included demonstrating the functioning of (relevant parts of) the model and the generated output data to persons working at the workplaces involved in the Change Management process. This lead to the fine-tuning of several aspects of model behavior, e.g., the interruption of a task or a consultation by a high-priority event (production problem).

The replicative validation was carried out by performing t-tests for 60 model replications, where each replication had a span of one working month. As mentioned above, the gathered quantitative data were considered to cover 92% of the actual situation, therefore a level of confidence of 92% was used for performing the t-tests. It was concluded that there was no significant difference between the output values generated by the model and the empirical ones.

7.2.5 Step 5: Experimentation and results interpretation

The working of the simulation model of the Change Management process can be examined by installing the model from the CD-ROM available as an appendix to this book (see appendix B). In order to illustrate the benefits of using the developed simulation template part of the model has been built using the simulation constructs from the template while another part has been built using the standard simulation blocks offered by *ARENA*®. Below we summarize the experimentation with the model and the obtained results in relation to the goals of the test case.

As explained in sub-section 7.2.1 there were two main goals of the test case: to provide insight into the working of the Change Management process and to provide an estimation of the time spent by the persons involved in the process on carrying out tasks directly related to the process.

Insight into the work of the Change Management process was provided by visualizing the dynamic interaction of the different process components in the course of a simulation run. The stochastic way of generating events in the model and the explicit time dimension offered by simulation helped to represent the probabilistic nature of the real-life process and capture the arrival and processing of information objects, the dynamic determination of the activities that had to be carried out depending on the (stochastically generated) characteristics of these objects, as well as the change of workloads and activity durations in the course of time.

In order to estimate the time spent by the persons involved in the process on tasks directly related to it samples of the values of the performance indicator described above were taken for 100 model replications with a span of one month. Within each model replication the data about arrivals of information objects, their characteristics and the duration of the different activities were generated in a random way within the ranges described in sub-section 7.2.2.2 and varied dynamically in the course of the simulation run. Based on the data gathered from the replications, a minimum, maximum and average value for the time spent on tasks directly related to the Change Management process were calculated for the *Service Coordinator* and the *Quality Controller* workplaces. These values are given in table 7.3.

	Percentage of time spent on tasks directly related to the Change Management process (hours per week)			*Average working time (hours per week)*
	Minimum	*Average*	*Maximum*	
Service Coordinator	2.7 (7.5%)	6.4 (17.8%)	7.6 (21.1%)	36
Quality Controller	24.5 (68.1%)	26.7 (74.2%)	30.2 (83.9%)	36

Table 7.3: The percentage of time spent on tasks related to the Change Management process

Based on the data provided in the table, it can be concluded that the percentage of time spent by a *Service Coordinator* on tasks directly related to the Change Management process varies significantly depending on the frequency of arrivals of client service requests and the time needed for their realization. The percentage of time for the *Quality Controller*, on the other hand, is more stable and takes a bigger portion of the total amount of the available working hours per week, which is related to the fact that the majority of tasks of this workplace were related to the process, as well as to the relatively constant character of the frequency with which RFC’s were submitted by the Technical Management departments.

7.3 Conclusions

In this chapter the application of the conceptual basis and the set of modeling constructs described in chapter 4, as well as the approach for ICT management simulation described in chapter 5 was presented based on a second test case in a real-life situation. The test case was carried out in the ICT department of a public services organization and focused on the working of the Change Management process within that department. Similar to the test case described in the previous chapter, the purpose of the case was twofold: first, it had to illustrate the way in which the elements mentioned above can be applied in practice and validate their usability and applicability, and second, it had to provide insight into the working of the Change Management process, model the different tasks and activities carried out as part of it, and provide an estimation of the percentage of time spent by people involved in the process on tasks directly related to it. With regards to this, the following conclusions can be made:

- The test case illustrated once again the way in which the conceptual framework can be applied for identifying the basic objects that were part of the process under investigation and for defining their characteristics and functionality.
- The way in which the object classes of the object class library for ICT management simulation can be used for building a simulation model was explained and their application for building a simulation model in a real-life situation was described.
- The way in which the approach for building ICT management simulation models can be used in practice to carry out a simulation study was described, the application of its steps was demonstrated and the way of building and using the different models that are part of it was explained.
- By modeling and visualizing the tasks and activities carried out as part of the Change Management process, the used equipment, the processed information objects, as well as the interaction with parties external to the process, insight into the functioning of the process was provided and the way in which client service requests and the resulting RFC’s, as well as RFC’s submitted by the Technical Management departments were handled was explained.
- The developed simulation model of the Change Management process was used to provide an estimation of the time spent by the persons working at the *Quality Controller* and *Service Coordinator* workplaces on tasks directly related to the process.

Chapter 8

Summary

8.1 Introduction

Information and Communication Technology (ICT) is conquering the modern world at an ever-increasing pace. It has become a critical survival factor and a strategic weapon for modern organizations, which adopt it on a large scale in order to be able to carry out their business processes and to stay competitive in the global markets of today. More and more diverse software and hardware infrastructures are being used; they are becoming larger and increasingly sophisticated. In addition, the number of people involved in ICT management is increasing, the dependencies and interrelationships among the different aspects of ICT management are becoming more and more complex, and ICT budgets keep growing.

This results in a continuous increase in the complexity and volume of ICT management and makes its effective and efficient management a challenging task. In order to assist ICT managers with this task different ICT management approaches are used increasingly in the contemporary ICT management organizations. However, there are a number of issues which impede the implementation of these approaches in practice. Among these issues are lack of clarity about the way in which an approach can be applied in a concrete situation, insufficient insight into the activities carried out as part of ICT management and their interdependencies, and a lack of tools which can be used to accurately predict the result of a proposed change in the ICT management organization.

The research presented in this thesis deals with the use of animated simulation for addressing these issues. The objective of the research was to investigate the advantages offered by animated simulation for modeling ICT management processes and to create a basis for its use in practice. In the following paragraphs a summary of the most important findings of the research is provided and directions for future research are proposed.

8.2 Research Question

The research was carried out as part of the research program on ICT management simulation of the chair *Information Strategy and Management of Information Systems* of the Faculty of

Information Technology and Systems of the Technical University Delft. The research program focused on the use of simulation for modeling ICT management processes in order to gain insight into their functioning, characteristics and interrelationships. An ICT management simulator was built as part of this program (see fig. 1.1). The simulator offered an opportunity to study the changes in different characteristics of ICT management processes by changing process parameters (e.g., queue length and processing speed) in the model. It also calculated a "score" for the processes based on the chosen parameter values and was used by students for carrying out assignments as part of the course on ICT management

Although the use of animated simulation for modeling business processes has been gaining popularity in the last 10 years, there is currently very little research reported in the literature with regard to its use for modeling ICT management processes and, therefore, little is known about its advantages and disadvantages. There is also a lack of clarity about the aspects of ICT management processes that have to be captured in a simulation model and the tools and steps that are needed in order to build such a model in an effective and efficient manner.

In relation to this, the main research question for the present research project was formulated as follows:

> ***Main Research Question:***
>
> *What theoretical developments and practical facilities are necessary for applying animated simulation for the modeling of ICT Management processes?*

In order to answer the main research question we formulated the following four research sub-questions:

- Which aspects of the daily ICT management practice are relevant to the building of simulation models of ICT management processes and how they can be used for defining a conceptual basis for developing such models?
- What kinds of facilities are necessary for building animated simulation models of ICT management processes, and how can they be developed?
- What approach can be used in order to build an ICT Management processes simulation model in an effective and efficient way, and what are the steps that have to be followed?
- How can the conceptual basis, approach and facilities for simulating ICT Management processes be applied in practice for modeling such processes?

8.3 Explorative Case

The literature study carried out as part of this research showed that there is currently little experience with the development and use of simulation models of ICT management. In addition, the few cases of ICT management simulation reported in the literature focus on specific technical aspects, and do not provide a generic basis for representing the processes and their constituent components in a simulation model. As a result of this, at the onset of the research there was a lack of clarity about two aspects of the development of simulation models of ICT management processes: 1) which characteristics of ICT management processes should be captured in a simulation model, and 2) what specific capabilities and functionality the simulation model should offer.

In order to gather more information about these aspects and gain insight into them we carried out an explorative case in an organization in The Netherlands. The objective of the case was to identify generic characteristics of ICT management processes relevant to the building of simulation models and to define requirements about the capabilities and functionality of such models. The results obtained in the course of the case can be summarized as follows:

- During the explorative case a number of generic characteristics of ICT management processes were identified. On the basis of these characteristics generic elements of the process structure were defined, which included the *information objects* used to exchange information, the *tasks*, into which the work is divided and the *activities* they consist of, the *equipment* used to carry out these tasks, the *workplaces* at which the tasks are carried out and the *workers* working at these workplaces.
- Implementation-specific characteristics of ICT management processes were also identified in the course of the case. These characteristics depend on the concrete implementation of the processes and include the concrete implementation of the generic elements of the process structure, the logic guiding the flow of information objects and the selection and execution of tasks at the workplaces, as well as the quantitative information about the frequency of occurrence of certain events in the processes and about the duration of the tasks and activities carried out as part of them.
- Based on the identified process characteristics, we defined requirements with regard to the capabilities and functionality that should be offered by simulation models of ICT management processes.

The results of the explorative case formed the basis for developing the framework and the approach for simulating ICT management processes discussed below.

8.4 A Framework for Simulating ICT Management Processes

In order to provide a conceptual basis and simulation facilities for modeling ICT management processes, a framework for simulating such processes was proposed as part of this research. The framework consists of a conceptual framework and a set of modeling constructs for ICT management simulation. The conceptual framework consists of a set of generic concepts for simulating ICT management processes based on the generic process elements identified as part of the explorative case and provides a description of their basic characteristics and relationships. The set of modeling constructs is based on the conceptual framework and is defined in the form of a library of object classes for simulating ICT management processes. The characteristics of the conceptual framework and the library of object classes can be summarized as follows:

- The conceptual framework offers a structured conceptual basis for building simulation models of ICT management processes. It includes concepts based on the generic process elements identified as part of the explorative case and provides a description of their basic characteristics, behavior and relationships.
- The library of object classes for simulating ICT management processes consists of simulation constructs defined on the basis of the described conceptual framework. The

constructs capture the characteristics and behavior of the elements of the conceptual framework taking into account the requirements specified during the explorative case. They provide the means for modeling the tasks and activities carried out as part of the processes under investigation, the workplaces and the people working there, the equipment used, the information flow within the processes and the rules guiding this flow and the work in the workplaces.

- The library of object classes was implemented as a simulation template in the *ARENA*® simulation environment. The parameters available for configuring the characteristics and functionality of the modules of the template as well as their visualization have been described. The way of modeling specific aspects and situations (e.g., the interruption of a task by a task with higher priority, the interactions taking place at the workplace or the way in which the result of a processing requested by an IT worker and carried out somewhere else in the model is processed) has been explained.

The framework for simulating ICT management processes provides a conceptual basis and facilities for building simulation models of ICT management processes. The modeling constructs developed as part of the simulation template described above are included in the CD ROM accompanying this thesis.

8.5 A Step-by-Step Approach for Simulating ICT Management Processes

In order to describe the steps that have to be taken to build a simulation model of ICT management processes, a step-by-step approach for simulating such processes was proposed as part of this research. The main characteristics of the approach can be summarized as follows:

- The approach consists of a sequence of steps that have to be carried out in order to build a simulation model of ICT management processes in an effective and efficient manner.
- For each step of the approach the goal was described, as well as the activities that have to be carried out as part of the step. The content of these activities, the way in which they have to be carried out and their results were explained.
- In the description of the tasks and their constituent activities emphasis was laid on aspects specific to the simulation of ICT management processes and guidelines were provided with regard to the use of the conceptual framework and the object class library described in this thesis.
- The steps of the approach were presented in the logical sequence in which they should be carried out. However, in practice the result of a certain step or activity may create the need to carry out a certain step or activity again. Therefore, the steps and their constituent activities may be carried out in an iterative rather than sequential manner.

The step-by-step approach and the framework for simulating ICT management processes described in the previous paragraph were used as a basis for carrying out the two test cases described below.

8.6 Two Test Cases

Two test cases were carried out as part of this research in two organizations in The Netherlands. The goal of the cases was to describe the way in which the framework and the approach for simulating ICT management processes can be applied in practice and to validate the ideas, techniques and elements presented as part of them. The achieved results can be summarized as follows:

- The test cases illustrate how the conceptual framework can be applied to identify the basic objects that are part of the processes under investigation and to define their characteristics and functionality.
- We showed how the object classes of the object class library for ICT management simulation can be used for defining the structure of the simulation model and how the developed modeling constructs can be used for building a simulation model in a real-life situation.
- We described how the approach for building ICT management simulation models can be used in practice to carry out simulation studies, how its steps can be carried out and how the different models that are part of these steps can be built and used.
- By modeling and visualizing the tasks and activities carried out as part of the processes under investigation, the used equipment, the processed information objects, as well as the interaction of the workplaces that were in the focus of the test cases with parties that were outside of this focus, insight into the functioning of the processes was provided and the relationships among the different components of the processes were explained.

The test cases were also used to explore the suitability of animated simulation for modeling ICT management processes and to assess its advantages and disadvantages compared to other modeling approaches. The models developed as part of the cases are included in the CD ROM accompanying this thesis.

8.7 Recommendations for Future Research

Having in mind that the research presented in this thesis is a study in a field where very little previous research was available, further research is needed to validate the ideas presented as part of it. There are a number of areas on which future research on the topic can focus. We would like to recommend three of these areas as directions for further research.

Firstly, taking into account that in many organizations several different ICT management processes are implemented and there are often issues with regard to the coordination of these processes and the way they work together, we suggest that animated simulation be applied to model not only a single process, but several processes simultaneously. In this way it can be used to visualize how the processes work and to provide insight into their dynamic communication and interdependencies.

Secondly, the use of workflow management systems for supporting and optimizing business processes is gaining popularity. Therefore we suggest that further research is carried out in order to investigate the way in which the results of the current research can be related to workflow management systems and the reference models they use in order to determine in which way these systems and models can be applied together with animated simulation for analyzing and optimizing ICT management processes.

Thirdly, as globalization and geographical dispersion in ICT management become an increasingly common practice among multinational companies and organizations, we suggest that further research is carried out into the application of animated simulation for modeling distributed ICT management processes in order to provide insight into how they work, how they are coordinated and how they perform.

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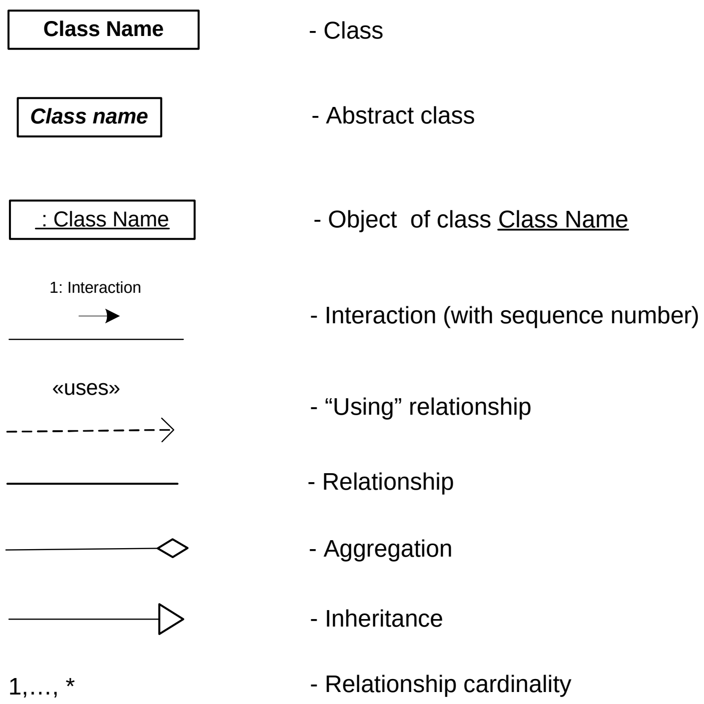
Appendix A

Class Diagrams in UML Notation

The class diagrams presented throughout this book were built using the notation described in (Booch, 1995). However, in the course of the research UML has gained popularity as a tool for object-oriented modeling and is used increasingly as the methodology of choice in object-oriented analysis and design. Therefore, in the following paragraphs the class diagrams presented in the previous chapters are depicted using UML notation. The symbols of this notation used in the figures can be summarized as follows:



The class diagrams used in this thesis are presented below. In order to improve the readability of this text the original numbering and names of the diagrams have been used in the figures below.

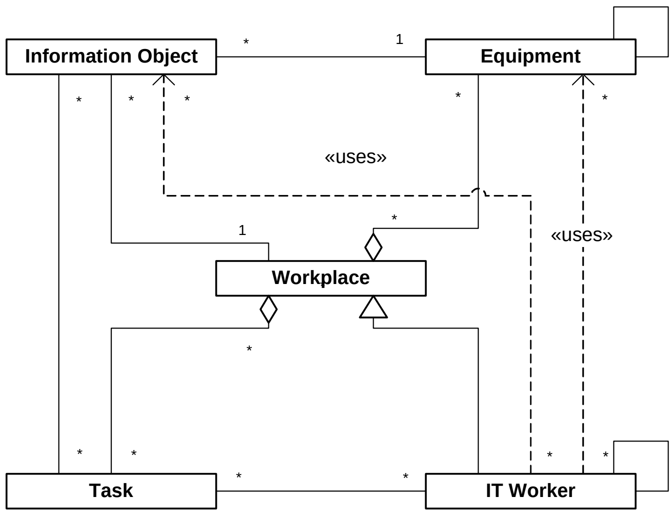


Figure 4.4: The conceptual object model of the problem domain

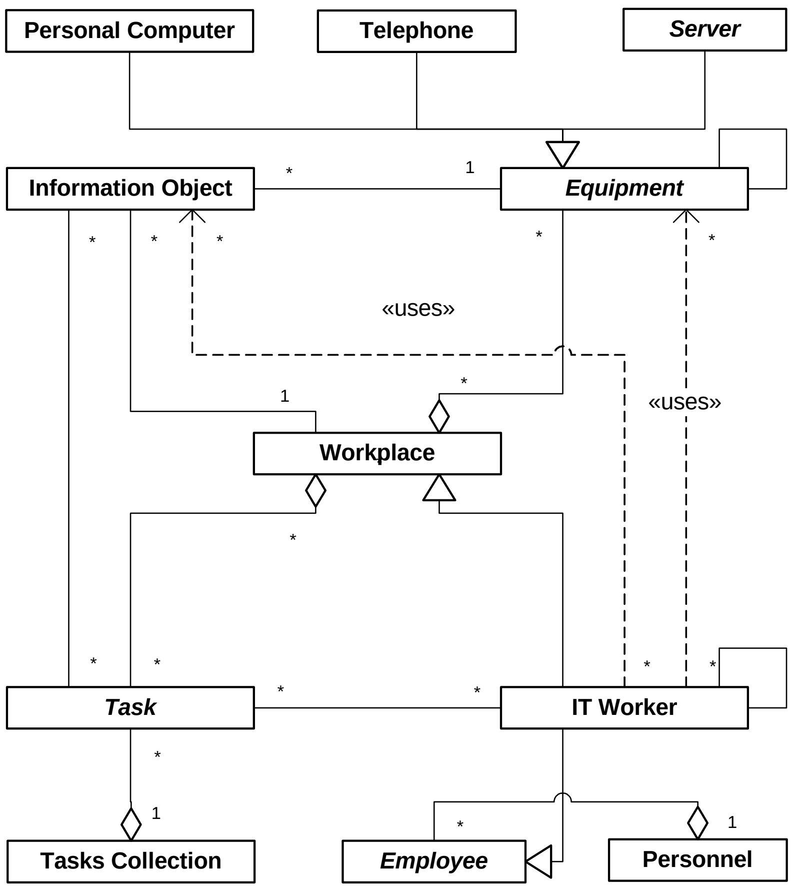


Figure 4.5: The structure of the object library

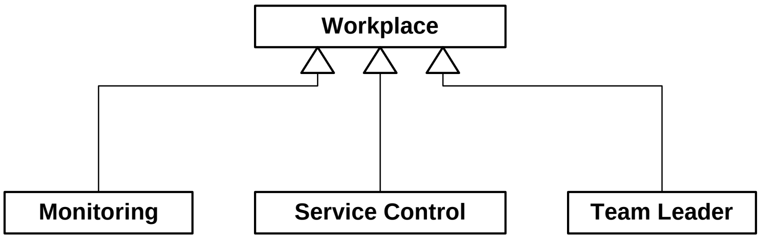


Figure 5.2: The *Workplace* classes of the Incident Management process

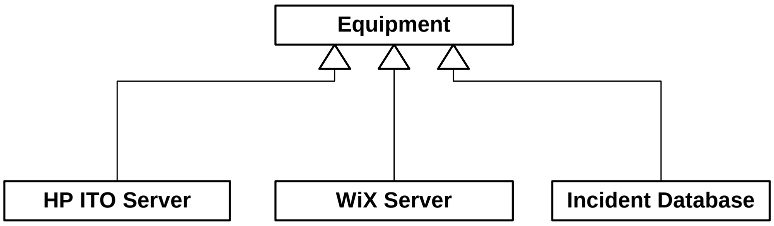


Figure 5.3: The *Equipment* classes of the Incident Management process

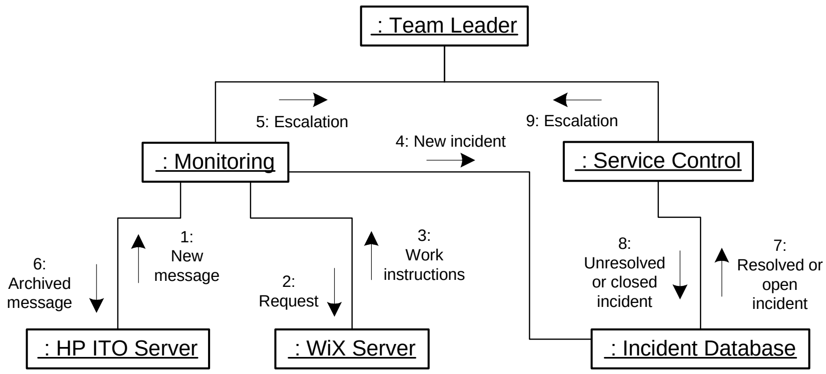


Figure 5.5: The *interaction diagram* of the Incident Management process

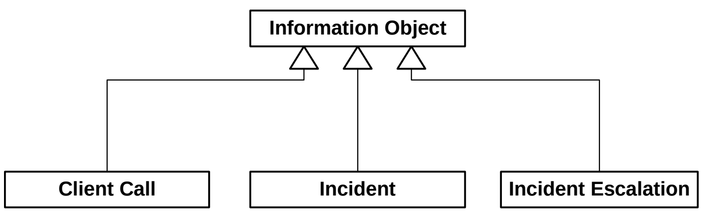


Figure 6.2: The three new *Information Object* classes

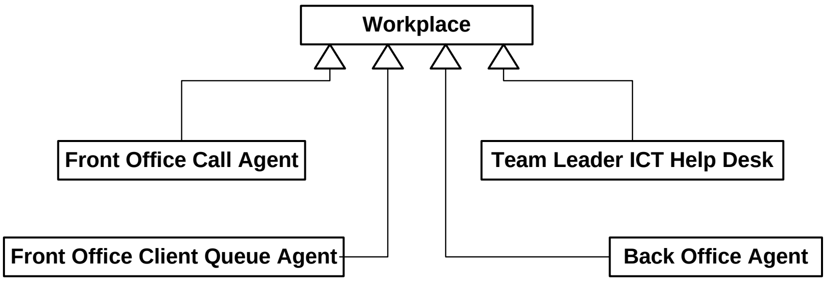


Figure 6.4: The four new *Workplace* classes

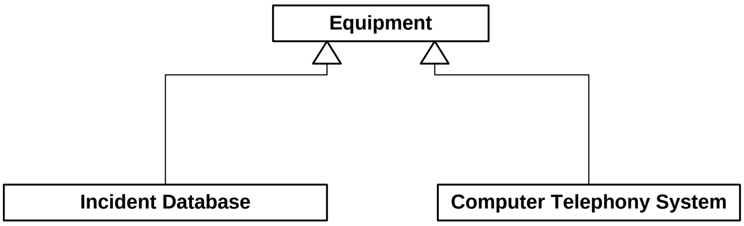


Figure 6.5: The two new *Equipment* classes

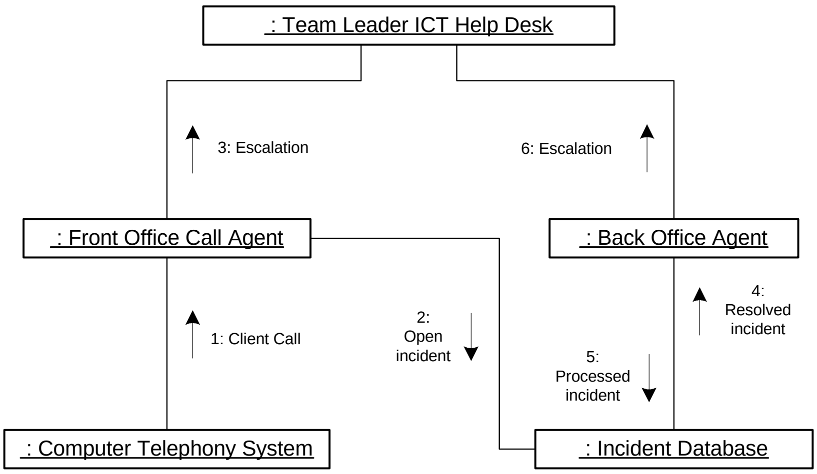


Figure 6.7 (a): The interaction diagram of the ICT Help Desk

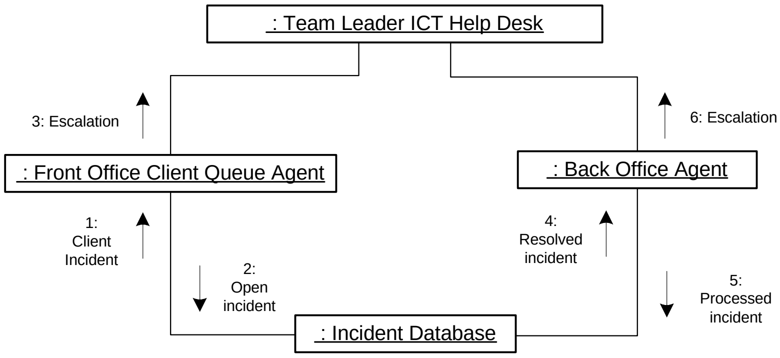


Figure 6.7 (b): The interaction diagram of the ICT Help Desk

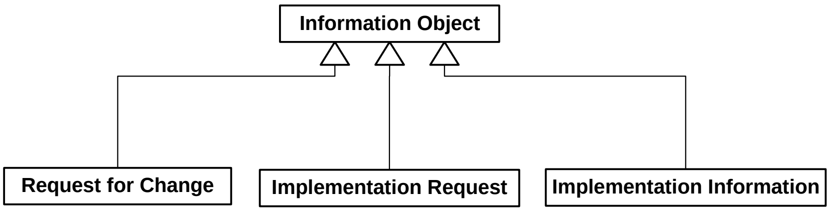


Figure 7.2: The three new *Information Object* classes

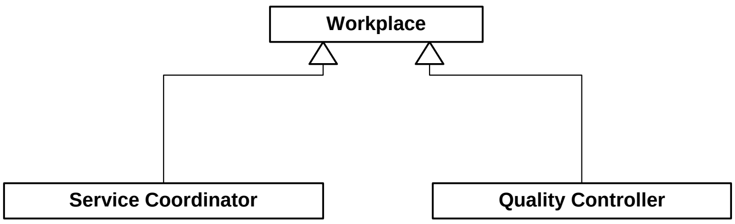


Figure 7.4: The two new *Workplace* classes

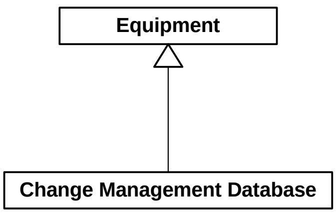


Figure 7.5: The new *Equipment* class

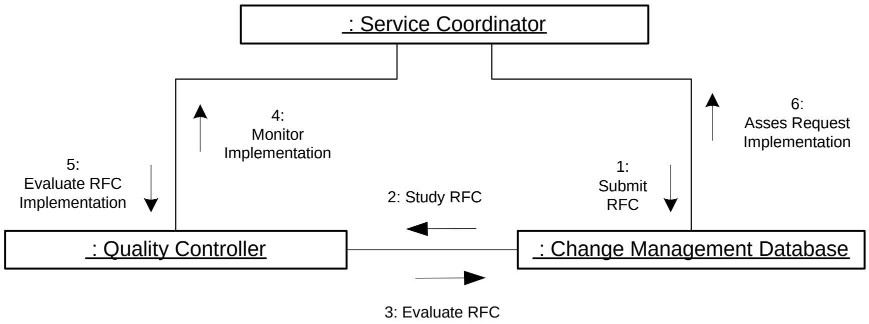


Figure 7.7: The interaction diagram of the Change Management process

Appendix B

Accompanying CD ROM

The simulation template and the simulation models developed during this research are included on the CD ROM accompanying this book. In order to be able to study and run the models a demonstration version of the *ARENA®* visual simulation environment is also included on the CD ROM.

The CD ROM is structured as follows. The files are divided into three directories: *Arena*, *Documents* and *Dissertation Files*. The *Arena* directory includes the installation files of *ARENA®*. The *Documents* directory includes the files *Installation Instructions.doc* describing the steps that have to be taken to install *ARENA®, Template Description.doc* containing a description of the developed simulation template and *Test Case A.doc* and *Test Case B.doc* containing a description of the implementation of the simulation models developed as part of the research.

The *Dissertation Files* directory includes two subdirectories: *Templates* and *Model Files*. The subdirectory *Templates* contains the developed simulation template as well as other template files necessary to run the simulation models. The *Model Files* directory includes the files that are part of the two simulation models. For instructions on how to install and run these models refer to *Installation Instructions.doc*.

Summary in Dutch

Een stap voorwaarts in de theorie en praktijk van ICT beheersimulatie

Introductie

Informatie en Communicatie Technologie (ICT) verovert de moderne wereld steeds sneller. ICT is zowel een kritische overlevingsfactor als een strategisch wapen geworden voor moderne organisaties, die haar op grote schaal toepassen om hun bedrijfsprocessen uit te kunnen voeren en om te kunnen blijven concurreren op de globale markten van vandaag. Steeds meer verschillende soorten software en hardware infrastructuren worden gebruikt; ze worden steeds groter, en steeds geavanceerder. Daarnaast houden steeds meer mensen zich bezig met ICT beheer, de afhankelijkheden en onderlinge relaties tussen de verschillende aspecten van ICT beheer worden steeds complexer, en de ICT budgetten van organisaties worden steeds hoger.

Dit alles zorgt dat er steeds meer ICT beheer nodig is, en het steeds complexer wordt om ICT te beheren, waardoor effectief en efficiënt beheer een uitdagende taak wordt. Om ICT managers bij het uitvoeren van deze taak te helpen, passen moderne ICT beheerorganisaties diverse ICT beheermethodieken toe. Er zijn echter verschillende problemen die het lastig maken om deze methodieken in de praktijk toe te passen. Voorbeelden daarvan zijn onduidelijkheid met betrekking tot de manier waarop een bepaalde methodiek in een concrete situatie toegepast kan worden, onvoldoende inzicht in de activiteiten die worden uitgevoerd als onderdeel van ICT beheer en in hun onderlinge afhankelijkheden, en gebrek aan middelen die gebruikt kunnen worden om nauwkeurig te voorspellen wat het resultaat is van een geplande wijziging in de ICT beheerorganisatie.

Het in dit proefschrift beschreven onderzoek richt zich op het gebruik van geanimeerde simulatie voor het aanpakken van bovenstaande problemen. De doelstelling van het onderzoek was om de voordelen van geanimeerde simulatie voor het modelleren van ICT beheerprocessen te bestuderen en een basis te creëren voor de praktische toepassing daarvan.

De volgende paragrafen geven een samenvatting van de belangrijkste resultaten van het onderzoek en doen enkele suggesties voor verder onderzoek.

Onderzoeksvraag

Het in dit proefschrift beschreven onderzoek is uitgevoerd als onderdeel van het onderzoeksprogramma op het gebied van ICT beheersimulatie van de leerstoel Informatiestrategie en Beheer van Informatiesystemen van de Faculteit Informatietechnologie en Systemen van de Technische Universiteit Delft. Het onderzoeksprogramma richt zich op het gebruik van simulatie voor het modelleren van ICT beheerprocessen om inzicht te krijgen in hoe deze functioneren, wat hun karakteristieken zijn en hun onderlinge relaties.

Hoewel in de laatste tien jaar geanimeerde simulatie steeds vaker wordt gebruikt voor het modelleren van bedrijfsprocessen, is er tot nu toe erg weinig onderzoek gepubliceerd met betrekking tot het gebruik van simulatie voor het modelleren van ICT beheerprocessen en is er weinig bekend over haar voor- en nadelen. Het is ook niet duidelijk welke aspecten van ICT beheerprocessen moeten worden beschreven in een simulatiemodel, en welke faciliteiten en stappen nodig zijn om een dergelijk model op een effectieve en efficiënte manier te kunnen bouwen.

Vanwege het bovenstaande formuleerden we de onderzoeksvraag voor dit onderzoek als volgt:

> *Welke theoretische ontwikkelingen en praktische faciliteiten zijn nodig om geanimeerde simulatie voor het modelleren van ICT beheerprocessen toe te kunnen passen?*

Om de onderzoeksvraag te kunnen beantwoorden zijn de volgende vier deelvragen geformuleerd:

- Welke aspecten van de dagelijkse ICT beheerpraktijk zijn van belang voor het bouwen van simulatiemodellen van ICT beheerprocessen en hoe kunnen die gebruikt worden voor het definiëren van een conceptuele basis voor het ontwikkelen van dergelijke modellen?
- Welke faciliteiten zijn nodig om geanimeerde simulatiemodellen van ICT beheerprocessen te kunnen bouwen en hoe kunnen die ontwikkeld worden?
- Wat voor aanpak moet gebruikt worden om een ICT beheersimulatiemodel op een effectieve en efficiënte manier te kunnen bouwen en wat zijn de stappen die gevolgd moeten worden?
- Hoe kunnen de ontwikkelde conceptuele basis, faciliteiten en stappenplan voor ICT beheersimulatie in de praktijk toegepast worden voor het simuleren van ICT beheerprocessen?

Beschrijvende praktijkstudie

De literatuurstudie die werd uitgevoerd als onderdeel van dit onderzoek liet zien dat er tot nu toe erg weinig ervaring is met het ontwikkelen en gebruiken van ICT beheersimulatiemodellen. Daarnaast richten de paar ICT beheersimulatiestudies die gepubliceerd zijn zich op specifieke technische aspecten, en vormen geen algemene basis voor het bouwen van simulatiemodellen van de processen en hun deelcomponenten. Als gevolg hiervan waren twee aspecten van het ontwikkelen van simulatiemodellen van ICT beheerprocessen onduidelijk in het begin van dit onderzoek: 1) welke karakteristieken van ICT beheerprocessen moeten opgenomen worden in een simulatiemodel, en 2) welke specifieke mogelijkheden en functionaliteit moet het simulatiemodel kunnen bieden.

Om meer informatie te verzamelen over deze aspecten en meer inzicht in ze te krijgen, voerden we een beschrijvende praktijkstudie uit in een organisatie in Nederland. Het doel van de praktijkstudie was om algemene karakteristieken van ICT beheerprocessen te identificeren die van belang zijn voor het bouwen van simulatiemodellen en om eisen te definiëren met betrekking tot de mogelijkheden en de functionaliteit die de simulatiemodellen moeten bieden. De resultaten van de praktijkstudie kunnen als volgt worden samengevat:

- Tijdens de studie werd een aantal algemene karakteristieken van ICTbeheerprocessen geïdentificeerd. Op basis daarvan werd een aantal algemene elementen van de processtructuur gedefinieerd. Die elementen zijn de *informatie-objecten* die gebruikt worden om informatie uit te wisselen, de *taken* waarin het werk is onderverdeeld en hun *deelactiviteiten*, de *apparatuur* die gebruikt wordt om de taken uit te voeren, de *werkplekken* waar de taken worden uitgevoerd, en de *medewerkers* die op de werkplekken werken.
- Implementatiespecifieke karakteristieken werden ook geïdentificeerd in de loop van de praktijkstudie. Deze karakteristieken zijn afhankelijk van de concrete implementatie van de processen en omvatten hoe de algemene elementen van de processtructuur specifiek worden geimplementeerd, de logica die wordt gevolgd bij het bepalen van het traject van de informatie-objecten binnen het proces en bij het selecteren en uitvoeren van taken op de werkplekken, en de kwantitatieve informatie over de frequentie waarmee bepaalde gebeurtenissen binnen de processen voorkomen en over de duur van de uitgevoerde taken en hun deelactiviteiten.
- Op basis van de geïdentificeerde proceskarakteristieken werden eisen gedefinieerd met betrekking tot de mogelijkheden en de functionaliteit die een simulatiemodel van ICT beheerprocessen zou moeten bieden.

De resultaten van de beschrijvende praktijkstudie vormde de basis voor het ontwikkelen van het raamwerk en het stappenplan voor het simuleren van ICT beheerprocessen die hieronder beschreven zijn.

Een Raamwerk voor ICT Beheersimulatie

Om een conceptuele basis en simulatiefaciliteiten voor het modelleren van ICT beheerprocessen te kunnen bieden is een raamwerk voor ICT beheersimulatie ontwikkeld als onderdeel van dit onderzoek. Het raamwerk bestaat uit een conceptueel raamwerk en een set modelleringcomponenten voor ICT-beheersimulatie. Het conceptuele raamwerk bestaat uit een aantal algemene concepten voor het simuleren van ICT beheerprocessen, die zijn gebaseerd op de algemene proceselementen die werden geïdentificeerd in de beschrijvende praktijkstudie en die een beschrijving geven van de basiskarakteristieken en onderlinge relaties van die elementen. De set modelleringcomponenten is gebaseerd op het conceptuele raamwerk en is gedefinieerd in de vorm van een bibliotheek van objectklassen voor het simuleren van ICT beheerprocessen. De karakteristieken van het conceptuele raamwerk en de bibliotheek van object klassen kunnen als volgt worden samengevat:

- Het conceptuele raamwerk biedt een gestructureerde conceptuele basis voor het bouwen van simulatiemodellen van ICT beheerprocessen. Het bestaat uit concepten gebaseerd op de algemene proceselementen geïdentificeerd tijdens de beschrijvende praktijkstudie en beschrijft hun basiskarakteristieken, gedrag en onderlinge relaties.
- De bibliotheek van objectklassen voor het simuleren van ICT beheerprocessen bestaat uit een aantal modelleringscomponenten gedefinieerd op basis van het conceptuele raamwerk. De modelleringscomponenten implementeren de karakteristieken en gedrag van de componenten van het conceptuele raamwerk, rekening houdend met de eisen gespecificeerd tijdens de beschrijvende praktijkstudie. Ze bieden middelen om de taken en hun deelactiviteiten, de werkplekken en de werknemers die daar werken, de gebruikte apparatuur, de informatiestroom binnen de processen en de logica die die stroom en het werk op de werkplekken aanstuurt te kunnen modelleren.
- De bibliotheek van objectklassen werd geïmplementeerd als een simulatiesjabloon (template) in de *ARENA*® simulatie-omgeving. De parameters beschikbaar om de karakteristieken en functionaliteit van de modules van de simulatiesjabloon te kunnen configureren zowel als hun visualisatie waren beschreven. We lieten zien hoe specifieke aspecten en situaties kunnen worden gemodelleerd, bijvoorbeeld het onderbreken van de uitvoering van een taak door een taak met hogere prioriteit, de interacties die op de werkplek plaatsvinden, of de manier waarop men het resultaat van een bewerking aangevraagd door een IT medewerker modelleert wanneer deze elders in het model verwerkt wordt.

Het raamwerk voor ICT beheersimulatie vormt de conceptuele basis en biedt faciliteiten voor het bouwen van simulatiemodellen van ICT beheerprocessen. De modelleringcomponenten van de beschreven simulatiesjabloon staan op de CD ROM die bij dit proefschrift toegevoegd is.

Een Stappenplan voor ICT beheersimulatie

Als onderdeel van dit onderzoek is er een stappenplan uitgewerkt die de stappen beschrijft die genomen moeten worden om een ICT beheersimulatiemodel te kunnen bouwen. De belangrijkste karakteristieken van het stappenplan kunnen als volgt samengevat worden:

- Het stappenplan bestaat uit een aantal stappen die genomen moeten worden om een ICT beheer-simulatiemodel op een effectieve en efficiënte manier te kunnen bouwen.
- Zowel het doel van elke stap als de activiteiten die uitgevoerd moeten worden als onderdeel van de stap zijn beschreven. De inhoud van de activiteiten, de manier waarop die uitgevoerd moeten worden en hun resultaat zijn uitgelegd.
- In de beschrijving van de taken en hun deelactiviteiten is de nadruk gelegd op aspecten specifiek voor het simuleren van ICT beheerprocessen en zijn richtlijnen gegeven met betrekking tot het gebruik van het in dit proefschrift beschreven conceptuele raamwerk en de bibliotheek van objectklassen.
- De stappen van het stappenplan zijn gegeven in de logische volgorde waarin die uitgevoerd zouden moeten worden. In de praktijk blijkt echter dat het resultaat van een

bepaalde stap of activiteit het nodig kan maken om een stap of activiteit opnieuw uit te voeren. Het is dus mogelijk dat de stappen en hun deelactiviteiten op een iteratieve in plaats van een sequentiële manier uitgevoerd worden.

Het hierboven beschreven stappenplan en het raamwerk voor ICT beheersimulatie waren de basis voor het uitvoeren van de twee toetsende praktijkstudies die hieronder beschreven zijn.

Twee Praktijkstudies

Twee praktijkstudies werden uitgevoerd in twee organisaties in Nederland als onderdeel van dit onderzoek. Het doel van de praktijkstudies was om een beschrijving te geven van de manier waarop het raamwerk en het stappenplan voor ICT beheersimulatie in de praktijk toegepast kunnen worden, en om de onderliggende ideeën, technieken en elementen te valideren. De bereikte resultaten kunnen als volgt worden samengevat:

- De praktijkstudies laten zien hoe het conceptuele raamwerk toegepast kan worden om de basisobjecten die deel uitmaken van de bestudeerde processen te identificeren en hun karakteristieken en functionaliteit te definiëren.
- We lieten zien hoe de objectklassen van de bibliotheek voor ICT beheersimulatie gebruikt kunnen worden om de structuur van het simulatiemodel te definiëren en beschreven hoe de ontwikkelde modelleringcomponenten kunnen worden gebruikt om een simulatiemodel te bouwen in een praktijksituatie.
- We beschreven hoe het stappenplan voor ICT beheersimulatie in de praktijk kan worden gebruikt, hoe de stappen kunnen worden uitgevoerd, en hoe de verschillende modellen die deel uitmaken van de stappen kunnen worden ontwikkeld en gebruikt.
- Om inzicht te geven hoe de bestudeerde processen functioneren en wat hun onderlinge relaties zijn, modelleerden en visualiseerden we de taken die als onderdeel van de processen uitgevoerd worden en hun deelactiviteiten, de apparatuur die wordt gebruikt, de verwerkte informatieobjecten en de interactie tussen de werkplekken waarop de praktijkstudies zich richtten en partijen buiten die focus.

De praktijkstudies zijn ook gebruikt om de toepasbaarheid van geanimeerde simulatie voor het modelleren van ICT beheerprocessen te bestuderen en haar voordelen en nadelen in vergelijking met andere modelleringmethodieken te kunnen beoordelen. De tijdens de praktijkstudies ontwikkelde simulatiemodellen staan op de CD ROM die bij dit proefschrift is toegevoegd.

Aanbevelingen voor Verder Onderzoek

Omdat het hier beschreven onderzoek een onderzoeksgebied betreft waarnaar nog weinig ander onderzoek is verricht en waarover weinig is gepubliceerd, is verder onderzoek nodig om de hier gepresenteerde ideeën verder te kunnen valideren. Er zijn een aantal aandachtsgebieden waar verder onderzoek zich op zou kunnen richten. Drie daarvan willen we aanbevelen als interessant voor vervolgonderzoek.

Ten eerste moet er rekening gehouden worden met het feit dat er in veel organisaties niet een, maar een aantal ICT beheerprocessen geïmplementeerd zijn, en dat er vaak problemen zijn met betrekking tot het coördineren daarvan en de manier waarop ze samenwerken. Daarom wordt hier voorgesteld dat geanimeerde simulatie gebruikt wordt niet alleen om een enkel proces te modelleren, maar een aantal processen tegelijk. Op deze manier kan inzicht verkregen worden in de manier waarop de processen functioneren en in hun dynamische communicatie en onderlinge afhankelijkheden.

Ten tweede wordt het steeds populairder om workflow management systemen te gebruiken voor het ondersteunen en optimaliseren van bedrijfsprocessen. Daarom wordt hier voorgesteld dat verder onderzoek wordt gedaan naar de relatie tussen de bevindingen van het huidige onderzoek en de workflowmanagement systemen en hun referentiemodellen om te bepalen hoe deze systemen en hun modellen kunnen worden gecombineerd met geanimeerde simulatie voor het analyseren en optimaliseren van ICT beheerprocessen.

Ten derde, aangezien multinationale bedrijven en organisaties steeds vaker geografisch gedistribueerd ICT beheer voeren, kan het verder worden onderzocht hoe geanimeerde simulatie toegepast kan worden om gedistribueerde ICT beheerprocessen te modelleren met als doel inzicht te krijgen in hoe deze werken, gecoördineerd worden en wat hun prestaties zijn.

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Many thanks to the staff at the TU Delft for their help throughout this research, and especially to Conny van Driel and Rina Abbriata for their secretarial support and to the technical support staff for taking care that the necessary hardware and software were available and working fine.

And last, but certainly not least, I want to thank my family for their support, understanding and help through all these years. They endured the long evenings and weekends I had to spend working on the research instead of giving them the attention they deserved, and created the home atmosphere I needed to successfully reach the finish of this endeavor.

Many thanks to all of you!

Ilian G. Ilkov

Delft, May 2004

List of Abbreviations

BO – Back Office
BPR – Business Process Reengineering
CAB – Change Advisory Board
CI – Configuration Item
CM – Change Management
CMDB – Change Management Database
CSIP – Central Service for Information Provisioning
ESM – Extended State Model
FO – Front Office
HD – Help Desk
HP ITO – Hewlett-Packard IT Operations
ICT – Information and Communication Technology
IIM – Information Infrastructure Management
IP – Internet Protocol
IS – Information System
ITIL – IT Infrastructure Library
ITPM – IT Process Model
ITSMRM – IT Service Management Reference Model
MCM – Management, Control and Maintenance of Information Systems
MOF – Microsoft Operations Framework
OOA – Object-Oriented Analysis
OOD - Object-Oriented Design
OOP - Object-Oriented Programming
PC – Personal Computer
RFC – Request for Change
RS – Real System

SLA – Service Level Agreement

SM – State Model

SME – Subject Matter Expert

SMT – Service Management Team

SNMP – Simple Network Management Protocol

TT – Trouble Ticket

WFMS – Workflow Management System

About the author

Ilian Ilkov was born in Popovo, Bulgaria on September 18th, 1971. He attended the "Asen Zlatarov" High School in Haskovo, Bulgaria from 1985 until 1990. Afterwards he studied Computer Science at the Technical University Sofia, Bulgaria specializing in computer technologies and received his M.Sc. diploma in 1997. The final thesis was carried out at the Technical University Delft and focused on simulating configuration management and network management processes.

He began his research on simulating ICT management processes at the Technical University Delft in 1997. During the research publications were made on international conferences and presentations were given for fellow researchers and during workshops on ICT management.

Since 2001 he is working as IT system engineer at the computer department of ABN AMRO Bank N.V. and focuses on the management, control and maintenance of the ICT infrastructure.