Modeling IT Operations to Derive Provider Accepted Management Tools

S. Abeck, C. Mayerl
University of Karlsruhe
Institute of Telematics, C&M IT Research
Zirkel 2
76128 Karlsruhe
Germany
Phone: +49-721-608-[6391|6390], Fax: +49-721-388097
E-mail: [abeck|mayerl]@telematik.informatik.uni-karlsruhe.de

Abstract

In this paper a process oriented approach to derive requirements on IT management tools is presented. The starting point is given by the processes that have to be carried out to run a distributed system. The better a management tool supports these processes the more useful it is from the viewpoint of the provider. Hence, the more accepted the tool is by the operators doing their work in the IT organization. The process model describing IT operations of a distributed networked system stems from an industrial project. The project goal was to introduce a process oriented quality management system into a complex IT environment. One of the operational processes of the model, the process Operation of Changes is described in more detail which demonstrates the method to derive demands on management tools from the process description. The result of this method is a collection of tools supporting request, commitment, performance and evaluation of an IT change. The integrated software architecture and the central software modules of our solution are outlined. The method described in this paper has been successfully applied to various fields of IT management.

Keywords

Process Model, IT Operations, Networked Systems, Management, Management Tools

Classification

D: C.2.3, D.2.9, D.4.4, H.4.1, K.6.2

1 Introduction

Operators of IT resources more and more become service providers. In this role a provider needs new concepts and management tools to provide services according

quality of service required by its customer. To guarantee quality of service parameters, such as availability or response time, the service provider should be able to control the complete process of IT service production. But, running computer systems and the network connecting these systems so far seemed to be an *art*. The most important characteristic of an art in this context means that you do not exactly know how something works since it depends on the intuition of people involved. In the past IT operations concepts rather depended on the intuition of operators. Rules gained from experience, controlled the way of how to run the computer and networking components. Most of the operation concepts were implemented by the operating systems running on the host systems. This situation has changed for the following two main reasons:

- The process of downsizing led to a stronger use of decentralized systems, such as UNIX workstations or Windows-NT PCs. These operating systems do not support operation concepts in the same way host operation systems do. Additionally, running a distributed heterogeneous system is much more complex than running a centralized homogeneous system.
- The overall goal of an IT service provider is no longer just to run the distributed system properly rather than to provide an IT service to its customer. A certain quality of service is demanded by the customer who in turn is willing to pay a certain price.

Either integrated or isolated network and systems management tools play an important role in an operation concept for distributed networked systems. From the perspective of a provider these tools are used to support certain tasks and processes that have to be fulfilled to provide IT services. This viewpoint of IT management differs from the viewpoint of a software developer who is interested in the management tools and the way these tools are implemented. For a provider the implementation of management tools should be as transparent as possible. From his perspective a tool is nothing but an (computer-based) aid which gives as much support as possible to the staff performing the process. Therefore the central statement of investigations outlined in this paper is: To be able to build provider accepted management tools it is necessary to understand the processes of IT operations.

In the past the necessity to investigate aspects of IT operations in order to build a formal foundation for a sound operating concept was recognized either by industry or by researchers [Ema94, DHR93]; first solutions have been successfully implemented [CKo97, HAW96].

2 Aspects of IT Operations and Existing Frameworks

IT operations includes all aspects to run a given IT infrastructure and to provide a certain IT service. Therefore, basic elements that have to be investigated are:

1. IT infrastructure – hardware and software: These are the main objects of investigation in computer science. In the past the central goal was to design and implement hardware components, especially processors, and software components, either system software or application software. The question of how to run these IT components, i.e. the field of IT operations, is related to the design and implementation. Additionally it contains some further aspects which have to be investigated.
2. Functional support to run IT components: One of these aspects is tool support the area of integrated network and systems management has focused its work on [HAN98, LSS97]. The kernel of the network and systems management is the management architecture and its submodels, which build a kind of an abstract specification for integrated management platforms such as HP OpenView or NetView6000. Today a wide range of more or less useful management tools exists. They cover various functional aspects such as configuration, fault, performance, security, accounting that are prescribed by the functional submodel of the management architecture.
3. Service level agreements, service management: The major goal of an IT service provider running IT components of a networked system is to provide IT services according to a service level agreement (SLA). A SLA is a contract between the provider and its customer which describes the functionality of an IT service and quality of service guarantees mode by the provider. This aspect is covered by service management. The theoretical foundation of service management is given by the **Telecommunication Management Network** (TMN) framework [CKo97].
4. Tasks and processes: A further aspect of IT operations to be mentioned concerns the question of how an IT service is provided. This leads to the tasks and processes that have to be carried out by the service provider. The most complete and advanced work on that topic that might become an accepted framework in the future, is the **Information Technology Infrastructure Library** (ITIL, [CCT97, CCT94]).

3 A Process Model for IT Operations

The ITIL built a main basis for our model which describes the operation of a complex networked system. This model has been successfully applied to introduce a process oriented quality management system into a computing center where a staff of 250 people are running MVS host systems, UNIX and Windows NT workstations interconnected by Ethernet, FDDI and Datex-M.

A rough overview of the model is given in Figure 1. The goal of the providers' organizations is to provide services to its customers with a certain quality as described in a service level agreement. To provide IT services in turn certain tasks, such as planing, developing or training, have to be fulfilled. In what follows we focus on those services which require the operation of components

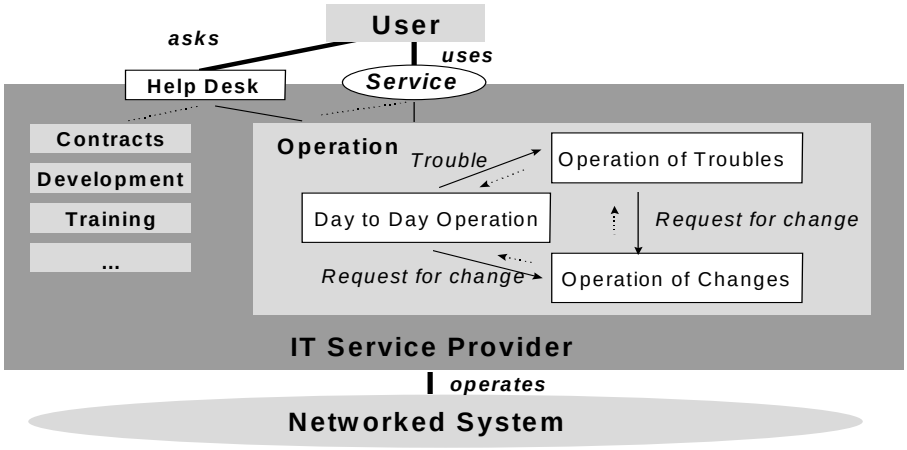

Figure 1: Overview of the process structure of an IT Service Provider

building the networked system (e.g. hubs, switches, hosts, workstations, PCs). Therefore in our model the task block of IT operations is divided into three operational processes. After a short description of each process the relationships between these processes are outlined.

3.1 Operational Processes

The starting point is a networked system, which has been planned and installed beforehand. Certain routine actions such as switching on, booting, monitoring the network and system components should not have negative influence on an IT service using resources of this networked system. The process of **Day to Day Operation** describes this kind of routine actions. In a 24 hour operation which is the normal case in professional IT environments, operation is organized in shifts. Besides the main action of monitoring the networked system, data backup and (re-) configuration of certain components are further actions of the process Day to Day Operation.

During Day to Day Operation deviations such as intermediate or total failures of network or system components are remarked. If these failures cannot be solved by applying some routine actions as part of the Day to Day Operation (e.g. reset of the component) a trouble is generated. Removing this trouble is the goal of the process **Operation of Troubles**. Hence the trouble has to be analyzed and diagnosed. The process is structured according to certain support levels. If a trouble cannot be diagnosed and solved on one support level it is propagated to the next higher level.

Evolution is a typical property of networked systems: Network and system components are exchanged or new versions of a system or application software applied in the networked system is introduced on one or more systems. If the manipulation to be executed on the networked system exceeds a certain level of

Table 1: Examples for operational situations

Part of the Distr. System	*Routine*	*Trouble*	*Change*
Network	Reset of a network component	Failure of a network component, that cannot be handled by a routine manipulation	Introduction of a new network component
	Switching a backup line	Loss of a connection	Adding Backup lines to the network
	Regular change of fans	Exchange of a defect network component	Introduction of a new network technology (e.g. ATM)
System	New entry of a user	User has no access	Change of security relevant user rights
	Reset of a system	Total or partial failure	Exchange of a defect system
	Regular backup	Failure during the backup procedure	Introduction of a new backup system
Application	New entry of a user to have access to the application	User has no access to the application	Introduction of a new application or application version
	Reconfiguration of I/O channels of the application		Mass configuration with strong impacts

complexity it cannot be part of the Day to Day Operation, instead it gets part of a process **Operation of Changes**. This process guarantees a planned and coordinated implementation of such complex manipulations, called changes. In particular planing and coordination of changes minimize the risk that something unexpected happens (e.g. failures or negative influence on neighboured components).

All three operational processes are tightly interconnected as shown by the process transitions described above and illustrated in Figure 1. It's not the model's purpose to define a routine manipulation, a trouble, or a change for a given provider organization. Table 1 gives an example how a concrete provider might differentiate between these three terms.

A precise assignment of situations occurring during IT operations to one of the operational processes is important since this defines the way the situation has be handled by the operational staff. The more complex routine manipulations are

allowed to be executed during the Day to Day Operation, the less transitions to the Operation of Troubles and the Operation of Changes will take place. This implies that the provider runs a higher risk since routine manipulations are less planned and less coordinated than changes are.

4 Deriving Demands on Management Tools from the Process Model

A detailed description of the processes is useful to analyze and prescribe the way a provider organization should run the networked system. This is a prerequisite to introduce a quality management system. We use the process description for another important and demanding purpose: we investigate what kind of (tool) support a provider demands in a way that a process can be executed as efficiently as possible. This leads to process oriented requirements on management tools and hence to provider accepted tool implementations as we will illustrate with the following example of the process Operation of Changes [AMa97].

4.1 The Process Operation of Changes

Many aspects that have to be covered by this process can be found in a management functional area. In literature it is referred to as Change Management [CCT94]. We have chosen the name Operation of Changes to stress that this process describes not only the management, i.e. monitoring and controlling but also the operation, i.e. executing the change on certain network or system components of the distributed networked system [DSW98].

The **process** can be subdivided into four phases: After a Request Phase where a change request (CR) is expressed, the CR has to be accepted and planned in a Commitment Phase. If the planning has been finished successfully, the change is executed in a phase that in literature is called Performance Phase [Sch96]. The process is concluded by an Evaluation Phase where experiences from the former phases are documented in a kind of change knowledge base.

In the following **actions** to be fulfilled by the staff in each phase of the process are investigated. As outlined in Figure 2, the goal is to derive **P**rocess **o**riented **M**anagement means (PoMs) to perform each action effectively and efficiently. A good and pragmatic understanding of each action and hence of IT operations is a prerequisite to define PoMs.

One of the first actions to be taken in the process Operation of Changes is to specify the change request. Therefore a specific PoM, which we call a **change order form** is needed to carry out this action of the process. The change order form is an information structure used to record the information that the initiator of a request for change has to fill in.

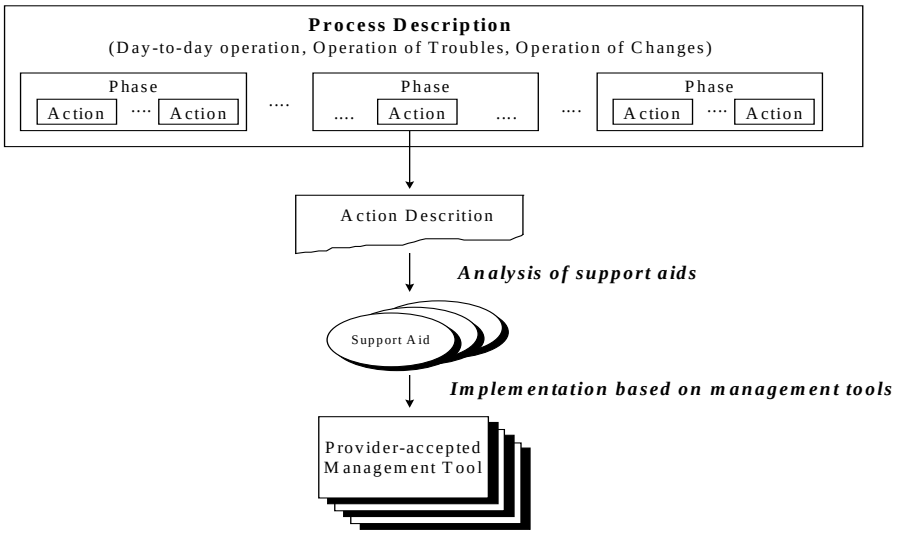

Figure 2: Overview of the taken approach

This includes

- identity of the initiator (name, telephone, e-mail)
- reason for the change request
- network and system components involved
- temporal aspects (e.g. deadlines, frozen zones)

Such a PoM change order form can be designed adequately only if we understand how it should be used in the overall process. We have analyzed how different network and system providers use such change order forms. In most cases these forms do only exist on paper, i.e. there is no computer-based solution for this PoM. Major demands of IT providers on a management tool implementing a change order form are:

- Flexible definition of the form structure: There are different types of changes which require different information fields on the form. Therefore, the form has to be customizable.
- Easy fill-in: Initiators and recipients of the form should be able to use text editors they are used to.
- Electronic transfer: Existing transfer mechanisms, such as WWW, e-mail, ftp or fax have to be supported.
- Check functions: Completeness and consistency are to be checked.

The next action has to classify the requested changes. The aim of this action is to schedule all requests during a certain time period e.g. a whole year. There are three main classes of changes [CCT94]:

- **Urgent** changes have the highest priority to be executed. The origin of an urgent change often is a great problem in the networked system which endangers the service level agreements with the users.
- **Normal** changes have to be queued considering deadlines and available resources in men and materials.
- **Impracticable** changes cannot be executed because there are no resources or no enabling technology.

The classification results in a queued list of accepted change requests which have to be done.

An aid supporting the classification and queuing of changes is the **change schedule**. It allows the provider to get a clear overview of all changes to be done during a certain time frame, e.g. one year. The change schedule considers the provider's resources and contains deadlines for each change. It also supports global execution control of each change. If a new urgent change is requested or if the deadline of an important change is endangered the change schedule could be adapted.

A PoM associated with a change schedule is the **task schedule** of each change. This aid contains all tasks that are required to execute a particular change. It also plans the responsibility and the employment of each task and underlines risks. Major demands on a management tool implementing change schedule and task schedule are:

- Getting an overview of all changes for a period of time e.g. for one year considering deadlines and resources in manpower and materials.
- Planning all tasks of an particular change considering responsibilities and risks.
- Controlling the execution of each change, verifying milestones and deadlines.

Because we say a change is a special kind of project, we can evaluate project management tools to plan and control changes.

The more knowledge a provider has about changes the faster and more exactly a task schedule can be produced. Therefore another PoM is the **change knowledge base**, which contains the history of all executed changes in terms of documented problems and risks. The experience from a post similar change (that is gathered in the change knowledge base) could speed up the planning of the current change. A management tool implementing the change knowledge base has to support

- the documentation of the current execution of a change underlining occurred problems,
- the effective and efficient investigation of the history of documented changes.

The list of actions and PoMs of the process Operation of Changes given above are examples. It has to be customized by each provider depending on the concrete scenario of a networked system. Also an evolution of the process Operation of Changes could cause the creation or destruction of actions and the PoMs involved.

A provider accepted management tool set has to take into account these requirements. We can implement such a solution by integrating existing management tools in a certain kind of platform which incorporates a mixture of workflow and groupware concepts. A concrete implementation is described in the next section.

4.2 Resulting provider accepted tool: Cooperative IT Change Control

The investigation of the process Operation of Changes and the PoMs lead to a provider accepted tool set to support the execution of changes. The demands influence the architecture of this tool set named **C**ooperative **I**T **C**hange **C**ontrol (CICC) [AMa97]. Figure 3 shows an overview of the architecture of CICC.
The better the management tools support the process the more useful they are from the viewpoint of the provider and hence, the more the IT provider is accepting these tools. Therefore the aim is to integrate the management tools into the process. This could be realized by a process oriented management platform shown in Figure 3. This platform and tool environment support the following functions:

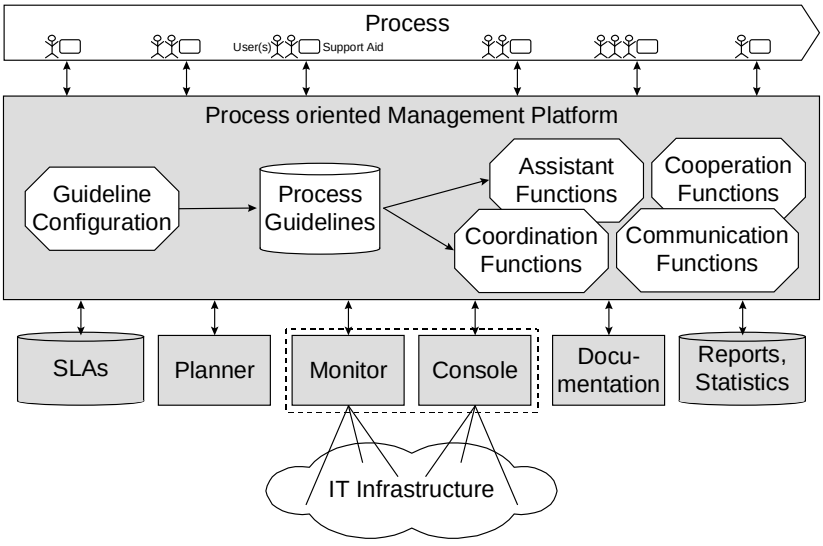

Figure 3: Integrated Management Platform

- The **communication and cooperation functions** provide the fundamental mechanisms of a distributed application environment to manage a networked system. The platform contains the technical mechanisms to transport information. This information is necessary to manage the networked system and to support the cooperation of remote roles. Therefore there are two kinds of communication directions: The first one is a *vertical* communication between the application modules involved as PoMs in the process and the networked system. This communication direction is often supported by management tools or mechanisms like network and systems management protocols enabling an application to monitor (and control) the networked system. Examples for such protocols are the simple network management protocol (SNMP) and the common management information protocol (CMIP). The second kind of communication mechanisms supports the *horizontal* communication and cooperation between roles using the distributed management application modules. These communication mechanisms (as for example email, www, ftp or even middleware like CORBA) use the networked system only as a transport medium. The platform allows to integrate tools into CICC using these communication mechanisms.
- Considering the process oriented approach the platform supports functions to guide the provider roles executing the process. This leads to what we call **assistant functions**. These functions provide a role oriented view on the operational process (in this case the Operation of Changes) and support the role to execute the necessary tasks efficiently. The desktop of an assistant consists of a list of scheduled tasks, a role specific overview of the process Operation of Changes and task specific forms to interact with the role. It is also possible to handle exceptions using other management tools. This flexibility is realized by the Guided Cooperation Concept (GCC).
- **Coordination functions** provide the assistant functions described before and coordinate the (technical) communication and cooperation between the management tools. They schedule the tasks to be executed and dispatch the tasks to the responsible roles. Typical examples of coordination functions are calendar and agent functions. Additionally there are functions to trigger an automated action if this is predefined.
- Other functions are the **guideline configuration** to define and customize guidelines describing the process and a **guideline repository** to gather the guidelines of a special provider. These functions help to configure the management tool environment CICC depending on the IT scenario. A **history function** which logs the current state of the process, supports the learning process: the logging data protocols the executed changes; these experiences could be used for further changes and help to adapt and improve the configuration of the process guidelines [WWT98].
- The **management application** tools or modules specified as PoMs are integrated in the process oriented management platform. Examples of

management applications are tools to monitor and control the networked system. These tools are known by the network and systems management and often are parts of integrated network and systems platforms like HP Openview, Cabletron Spectrum and Tivoli TME. Other important management tools supporting the process Operation of Changes are a database containing the service level agreements which have to be fulfilled by the process Operation of Changes, a planner to consider the operational tasks and the distribution of human resources. A management tool describing the current configuration of the networked system is necessary to execute the Operation of Changes. This tool is the implementation of the PoM configuration documentation. To support decisions, reporting tools evaluate and correlate management relevant informations and present the results as statistics. These management applications are only examples. The list of tools has to be customized depending on the concrete scenario.

To be effective and efficient in fulfilling the service level agreements in the process Operation of Changes it is necessary to integrate the management tools into the process. The process oriented management platform supports this kind of tool based integration.

4.3 Implementation experiences

The realization of a provider accepted management tool environment, like CICC, could be done in different ways. Investigations of providers have shown that the main criterion to differentiate realizations from each other is how to integrate the management tools into the process. The result is a migration from paper based to tool based process oriented management platforms. The following steps show a possible migration way when realizing such a management platform. Each step leads to a tool environment implementing a special issue of the tool integration.

1. A prerequisite for managing the networked system effectively and efficiently is the transparency of the operational processes (such as Operation of Changes). The description of the processes specifies how to run the networked system. Often there are paper based quality handbooks which are the result of undertaken certification projects [ISO9000]. These handbooks [IZ97, SCZ97] describe the processes and activities and refer to forms and management tools which have to be used. What obviously misses in most approaches, is the technical integration of management tools into the process. Projects in collaboration with industry have shown that the acceptance of quality handbooks is not very high among employees because of overwhelming maintenance and implementation in details. The experience shows that the knowledge about the process (e.g. Operation of Changes) must become closer to the usage of management tools to accept the process guidelines as an advantage.

2. The next step is to migrate the paper based handbook to a tool based process description. Because of intuitive usage web technologies are intensively propagated [ABMH98]. An important advantage is the efficient maintenance of the process information offered by a web server. Special web technologies like Active Server Pages (ASP) [Mic96] also allow to integrate management tools into the process description. In this case the web technology is the process oriented management platform shown in Figure 3. The guidelines are defined and implemented by e.g. HTML-editors and can be enriched by figures and multimedia features like conference systems etc.
   A web based prototype of CICC shows possible implementations of PoMs considering the demands of the provider: The change order form [Pet97] in this case is realized by a JAVA applet. This allows the initiator role to activate the applet inside a web browser. The usage of web browsers is intuitive and well understood today. It is also possible to integrate audio and video functions helping the user to fill in the change order form. Therefore, the applet represents a form which explains what kind of information has to be filled in. The applet in turn writes this information into a database connected to the WWW. Another module of CICC is the classifier which supports the provider to evaluate the requested changes. This application retrieves the requests from the database and displays them to the change manager. Another filling form supports the possibility to schedule the requests with priorities and deadlines. The classifier is also implemented in JAVA and can be activated in a web browser.
3. Keeping the advantages of web technologies we are working on a next step of a process oriented management platform. The main functions of the platform support the communication and cooperation between the roles executing the processes and management tools that are used. A preferred technology implementing such distributed application environments is the Common Request Broker Architecture (CORBA) of the Object Management Group (OMG). This middleware offers the necessary flexibility to integrate (legacy) management tools depending on the provider processes. In order to implement the coordination functions the CORBA platform has to be expanded. Offering assistant functions the web browser is used as front end because of its intuitive use.

5 Conclusion

The evolution of IT operators towards IT service providers is going on. Therefore the need to support processes providing the IT services will increase. The approach outlined in this paper has not only been applied to the field of IT changes. Two further successful projects which should be mentioned are:

- Design and implementation of a management solution to determine the network and system availability of a distributed system used in a large enterprise [HAW96].

- Tool Support of a telco provider to search for security attacks in the digital switched network [ABa97, KWe97].

Throughout all projects which cover different aspects of IT management in different IT environments, a top-down approach starting from the operational process a provider has to go through, was applied. All projects ended with tool implementations that hit the providers' demands and fit into the environment where the tools are applied.

So far the method is defined and applied in an informal way since it was not invented at the green table but it is the result from concrete industrial projects where a provider oriented approach was taken. We have seen that this approach leads to good results, i.e. useful, provider accepted tools which encouraged us to make the method more formalized, but still applicable. In concrete, we describe the operational processes by a modeling tool [Pro97] that is based on petri nets. The goal of the formalized description is to generate certain aspects of the management tools which support the execution of the process. This means that the process description is a kind of high level and provider oriented specification of tools that are needed to achieve effective and efficient IT operations.

The example of the process oriented environment has been expanded to other provider processes. There are still some fundamental questions for which we have not yet found a complete answer, such as: What kind of assistant functions does a service provider really need? What are the generic functions which the process oriented platform has to support? In which detail and granularity the guidelines should be described?

The innovative and important advantages of a process oriented management tool environment primarily is that it shows the viewpoint of the provider onto the management tools considering the context of a process (e.g. Operation of Changes). This is necessary to guarantee the quality of IT services defined by the service level agreements. The coordination and assistant functions can help to provide the IT services effectively and efficiently without loosing the flexibility needed to manage a networked system. Therefore it supports not only the technical functions to monitor and control the network, systems and application components of the networked system, but also the **communication and cooperation** of the staff playing different roles when the operational processes are carried out.

References

[ABa97]. S. Abeck, J. Batlogg: Security Logging in Telecommunication Networks, South-African - German Workshop on Telecommunication, November 1997.

[Abe96]. S. Abeck: Integrated Resource Management: A Process-Oriented Approach, European Summer School, Eunice´96, Lausanne, September 1996.

[ABMH98]. C. Ames, S. Burleigh, S. Mitchell, T. Huynh: Applications of Web-Based Workflow, Conference on System Sciences, Hawaii, 1998.

[AMa97]. S. Abeck, C. Mayerl: Process Descriptions as Basis for the Management of Networked Workstations, (in german), APS'97, Mai 1997.

[Amb96]. M. Amberg: The Benefits of Business Modeling for Specifying Workflow-Oriented Application Systems, University of Bamberg, 1996.

[CKo97]. G. Chen, Q. Kong: Integrated TMN Service Provisioning and Management Environment, Fifth IFIP/IEEE International Symposium on Integrated Network Management, San Diego, California, Mai 1997.

[CCT94]. CCTA: The IT Infrastructure Library: An Introduction, HMSO, London, 1994.

[CCT97]. CCTA: The UK Central Computer and Telecommunications Agency, http//open.gov.uk/ccza/cctahome.html and http//open.gov.uk/ccta/pubcat.html, 1997.

[Dad97]. P. Dadam: Praxis-Seminar: Prozeßmodellierung und Workflow-Management, Deutsche Informatik-Akademie, Ulm, 1997.

[DHR93]. G. Dean, D. Hutchison, T. Rodden, I, Sommerville: Distributed Systems Management as a Group Activity. IEEE Workshop on Systems Management, Los Angeles, 1993.

[DSW98]. R. Dewan, A. Seidmann, Z. Walter: Workflow Optimization through Task Redesign in Business Information Processes, Conference on System Sciences, Hawaii, 1998.

[Ema94]. M. Emanuel: Open Management - Addressing Real Business Needs. IEEE/IFIP Network Operations and Management Symposium, Orlando, 1994.

[Gür98]. J. Gürtler: Evaluation of Web-based Management Solutions with the Example of SAP R/3 (in german), Diploma Thesis, University of Karlsruhe, 1998.

[HAN98]. H.-G. Hegering, S. Abeck, B. Neumair: Intergrated Management of Networked Systems, dpunkt, to be published in 1998.

[HAW96]. H.-G. Hegering, S. Abeck, R. Wies: Corporate Operation Frameworks for Network Service Management, IEEE Communications Magazine Special Issue on Enterprise Networking, April 1996.

[Hol94]. D. Hollingsworth: Workflow Management Coalition - The Workflow Reference Model, Document Number TC00-1003, Brussels, 1994.

[IZ97]. Deutsche Telekom, Informationstechnisches Zentrum Darmstadt, Quality Management-Handbook (in german), 1997.

[Jab95]. S. Jablonski: Workflow-Management-Systems: Motivation, Modelling, Architecture (in german), Informatik Spektrum 18, Springer, 1995.

[KWe97]. D. König, F. Wernert: Security Management Concept for Digital Switches (in german), Diploma Thesis, University of Karlsruhe, 1997.

[Mic96]. Microsoft: Active Server Pages Tutorial, http://iis3.activeserverpages.com/iasdocs/aspdocs/roadmap.asp, 1996.

[ISO9000]. International Standardization Organization: Quality Management and Quality Assurance Standards - Guidelines for Selection and Use to the Formal Vote, 1987.

[Pet97]. M. Peter: RFC Input as Part of the Change Management Workflow (in german), Studienarbeit, University of Karlsruhe, 1997.

[Pro97]. Promatis: Manuals on the Process Modeling Tool `Income´, Promatis GmbH, 1997.

[RNG98]. C. Rolland, S. Nurcan, G. Grosz: A Unified Framework for Modeling Cooperative Design Processes and Cooperative Business Processes, Conference on System Sciences, Hawaii, 1998.

[Sch95]. A. Schill: Cooperative Office Systems: Concepts and Enabling Technologies, Prentice Hall, 1995.

[Sch96]. T. Schäl: Workflow Management Systems for Process Organizations, Springer, 1996.

[SCZ97]. Deutsche Telekom, Service- und Computer-Zentrum West: Extended Quality Management-Handbook (in german), 1997.

[WWT98]. C. Wargitsch, T. Wewers, F. Theisinger: An Organizational-Memory-Based Approach for an Evolutionary Workflow Management System – Concepts and Implementation, Conference on System Sciences, Hawaii, 1998.