Advances in Information Systems and Management Science
In dieser Reihe erscheinen ausgewählte Schriften aus der Wirtschaftsinformatik und der Betriebswirtschaftslehre. Sie stellen sowohl theoretisch fundierte Ergebnisse als auch deren Anwendung auf praxisbezogene Fragestellungen vor.

Workflow-based Process Controlling Systems provide companies with the ability to measure the operational performance of their business processes in a timely and accurate fashion. The combination of workflow audit trails with data warehouse technology and operational business data allows for complex analyses that can support managers in their assessment of an organization's performance. The increasing maturity of business process management and data warehouse systems enables the design and development of advanced process-oriented management information systems.

Michael zur Muehlen discusses the integration of workflow audit trail data with existing data warehouse structures and develops a reference architecture for process-oriented management information systems. Starting with an organizational and technical analysis of process organizations, this book provides a comprehensive documentation of business process management, workflow technology, and existing standardization efforts. The proposed reference architecture is validated in an industry context. A prototypical implementation of the reference architecture and its integration with a commercial business process management system are demonstrated as well.

This book is directed at both practitioners and academics in the fields of business process management, management accounting, and information systems.

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Foreword of the Editor

The process-oriented design of organizations has been subject of the business administration literature for more than 70 years. While numerous approaches for the implementation of process-oriented organizations exist, the methods and instruments of enterprise controlling are mostly aligned with functionally structured organizations. The design of enterprise-wide process controlling systems is hindered by the difficult sourcing of information about the operative execution of business processes.

Workflow management systems offer a solution to this problem. They support process-orientation through the automated coordination of activities, data, and resources. This coordination is based on a formal representation of the process to be automated, a workflow model, which is specified in the build time environment of the system. During the operation of a workflow management system, workflow instances are created from the workflow model and their execution is controlled through workflow enactment services. During the execution of workflow instances, traces of each instance are written to a process protocol, the so-called audit trail, recording the behavior of each instance. This audit trail represents a detailed and precise collection of data about the operative process enactment within a company.

The use of audit trail data for process controlling purposes has only been analyzed partially in the literature. Two of the missing pieces are an operational approach to integrate this type of data into an existing controlling infrastructure, and an assessment, which controlling methods and instruments can be applied to the analysis of this data. The success of the emerging fields of Business Intelligence and Business Activity Monitoring relies on a solution to these problems.

Michael zur Muehlen addresses several important questions in this context. How can management understand and control automated work processes? How can highly regarded management control techniques such as Activity-based Costing (ABC) and Balanced Scorecard (BSC) be implemented and automated through the information logged by a workflow management system? What is the data and systems architecture for such advanced control systems? Can such systems be implemented in practice?

Positioned at the intersection of business administration and information systems, this is an important and original work. Based on an extensive investigation of existing workflow technology and standards, Mr. zur Muehlen's dissertation contains the most thorough and comprehensive investigation of the problem of achieving organizational control through automated work systems. Extensive automation of work is inevitable. The ideas developed by Mr. zur Muehlen should therefore have lasting impact on management theory and practice.

Münster, June 2004 *Prof. Dr. Jörg Becker*

"How much time does it take to write a scientific paper? As much time as you have."
Jeffrey V. Nickerson

Foreword

In early 1995 I was a graduate student at the University of Münster, when Michael Rosemann - then senior lecturer in Münster - offered a seminar on workflow management technology. Curious as I was, I enrolled in the seminar, and soon I found myself analyzing the meta models of workflow management tools such as FlowMark, LEU, WorkParty, and CSE WorkFlow. I got hooked and - in retrospect - this seminar changed my life.

Almost ten years later, business process management and automation is still a hot research topic, even though three out of the four systems we analyzed back in 1995 disappeared from the market. The design and deployment of information systems for the automated coordination and enactment of business processes have proven to be popular topics, both in the academic and popular literature. Nevertheless, the majority of workflow-related publications are driven by technical considerations. A fundamental analysis of the impacts this technology has on organizations, their structure, and their management processes is still missing. This book is a first step to fill this gap. It is looking at workflow through a managerial lens, studying the role of process-enabled information systems for management decision making. In essence, we discuss the integration of process-related audit data into management information systems, and the decisions managers can make based on this information.

It took me almost two years to rewrite this book from its original format as a dissertation and to finally release it for publication. Going over the material, I noticed two things. First: Jeff Nickerson's assertion about the duration of the academic publication process is correct. Secondly: Within two years, the standards that were originally discussed in the third chapter of this book have largely evolved; some have merged, and new ones have entered the marketplace. For this reason, this book has to strike a balance between the description of current developments and the explanation of fundamental concepts. I hope this balance has been maintained.

Although this book is a monograph, many people contributed to its creation. I was fortunate to be surrounded by some very bright and talented people who allowed me to bounce ideas back and forth, and who provided a test bed for some of the more academic concepts developed in this book. Their ideas, inspirations, and comments have hopefully improved the quality of what you are about to read. I appreciate the assistance of all these people in helping me create this book. Should you notice any mistakes - they, of course, are all my own. Should you feel inclined to send questions or comments, I will be more than happy to answer to feedback sent to *michael@workflow-research.de*. Eventual errata will be documented at the web address *http://www.workflow-research.de/Publications/Book/Errata*.

I am extremely grateful to Prof. Dr. Jörg Becker, who provided me with an unparalleled amount of freedom for my research work. He allowed me to present my ideas at numerous national and international conferences, and was open to pursue new ideas in every area I wandered in. He also provided timely encouragement and useful criticism of the concepts. Thank you for five great years.

Prof. Edward A. Stohr agreed to co-supervise this work. I am incredibly indebted to him for his methodical insights, topical guidance, and critical discussions of the contents presented in this book. In addition, he has opened many doors in the American academic community for me that otherwise might have remained closed. He offered me to join Stevens Institute of Technology, where I look forward to our continued collaboration.

Prof. Dr. Michael Rosemann introduced me to the world of academic research and sparked my interest in process automation and workflow management. His guidance, enthusiasm, and creativity opened a new world for me that continues to be both fascinating and intriguing. Moreover, he is not just a colleague, but also a great friend - independent of longitude and latitude. All the best to Brisbane.

I had the pleasure to work with three brilliant students on the *Cassandra* project - Björn Blum, Henning Plöger, and Tobias Rieke, who put many hours of hard work into turning the conceptual process controlling ideas into a working prototype. Their contribution to this work is immense, and I would like to thank them for all of it.

Dr. Marc Gille and Michael Johann of Carnot allowed me to play with their “baby” and were extremely supportive throughout many changing ideas and plans. Jon Pyke of Staffware graciously offered me access to the Staffware 2000 product, and Marc-Thomas Schmidt offered me helpful advice when I had questions regarding the IBM MQSeries products. The members of the Workflow Management Coalition provided an invaluable reality check for my ideas. I am especially indebted to Dave Hollingsworth, Charlie Plesums, Robert Shapiro, and Keith D. Swenson for many intriguing insights into the commercial world of workflow.

The project team at the enterprise case study consisted of Dr. Andreas Tietz, Robert Freier, Edith Deitermann, and my colleague Andreas Rottwinkel. They offered me valuable information and support regarding the insurance case and graciously allowed me to publish the insight gathered in the project.

My colleagues at the University of Münster provided me with priceless ideas, challenging thoughts, and constructive criticism at times when it was most needed. I would like to thank them all for five fascinating years. PD Dr. Roland Holten diligently read through the early drafts of this book and guided me back to the right track when my train of thoughts was in the danger of derailing. Dr. Christian Probst provided companionship, valuable ideas, and - most important - a dose of pragmatism when the topic seemed to grow out of bounds. Sebastian Beneloucif was incredibly helpful in managing the ever-growing list of references and went beyond the call of duty more than once in order to ensure a timely completion of this book. Maggie Bin Lai proofread the final draft, and Colleen Gibney shared her incredible talent for writing style with me.

A very special thank you goes to Nersel, *sevgilim esmerim*, who gives me love, support, and encouragement when I need it most. Seni çok seviyorum. My most heartfelt thanks go out to my parents Heinrich and Helga zur Mühlen, who have provided me with unconditional love and support throughout my education and my academic career. They have given my brother Christian and me the most open-minded environment imaginable and provided constant inspiration throughout the time of my dissertation. This book is dedicated to them.

Hoboken, NJ, June 2004 *Michael zur Muehlen*

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List of Abbreviations

ABC	Activity-based Costing
ACM	Association of Computing Machinery
API	Application Programming Interface
ARIS	Architecture of integrated Information Systems
BPEL4WS	Business Process Execution Language for Web Services
BPM	Business Process Management
BPMI	Business Process Management Initiative
BPML	Business Process Modeling Language
BPMN	Business Process Modeling Notation
BPR	Business Process Reengineering
BR	Business Reengineering
BPI	Business Process Improvement
BRC	Business Reconfiguration
CIMOSA	Computer Integrated Manufacturing Open System Architecture
CORBA	Common Object Request Broker Architecture
DBMS	Database Management System
EBNF	Extended Backus-Naur Form
ebXML	Electronic Business XML
e. g.	exempla gratiae / exempli gratia (Latin: for example)
EJB	Enterprise Java Bean
EPC	Event-driven Process Chain
et al.	et alii (Latin: and others)
etc.	et cetera (Latin: and other things)
GPSG	Generalized Process Structure Grammars
HTTP	Hypertext Transfer Protocol
i. e.	id est (Latin: that is)
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force

J2EE	Java 2 Enterprise Edition
KIF	Knowledge Interchange Format
MIT	Massachusetts Institute of Technology
MOF	Meta Object Facility
NIST	National Institute of Standards and Technology
OMG	Object Management Group
ORB	Object Request Broker
PIF	Process Interchange Format
PSL	Process Specification Language
SOAP	Structured Object Access Protocol
SQL	Structured Query Language
SWAP	Simple Workflow Access Protocol
SWOT	Strengths, Weaknesses, Opportunities, Threats
tpaML	Trading Partner Agreement Markup Language
UDDI	Universal Description, Discovery and Integration
UML	Unified Modeling Language
WAPI	Workflow Application Programming Interface
WiSt	Wissenschaftliches Studium
WfMC	Workflow Management Coalition
WfMS	Workflow Management System
WPDL	Workflow Process Definition Language
WSCI	Web Services Choreography Interface
WSCL	Web Services Conversation Language
WS-CDL	Web Services Choreography Description Language
WSDL	Web Services Description Language
WSFL	Web Services Flow Language
XML	eXtensible Markup Language
XPDL	XML Process Definition Language

1 Workflow-based Process Controlling - An Introduction

1.1 Organizational Design and Process Performance

Organizational structures[1] and their development is studied by a variety of disciplines, such as sociology, psychology, and economics. The goal of organizational research within the field of business administration is the development of viable and efficient structures for enterprises as self-contained economic units.[2] Much of 20th century organizational research is founded on the works of FAYOL[3] and TAYLOR[4]. While FAYOL researched the managerial structure of an enterprise, TAYLOR focused on the operational enactment of tasks as well as the design of organizational structures that support the efficient execution of these tasks. The ideas devised by TAYLOR have dominated organizational research until the 1970s and can still be found in many enterprises today.[5] Until the 1970s the functional separation of tasks was appropriate for existing market conditions. Since then, increasing market segmentation and shorter product life-cycles, among other factors, have led both businesses and researchers to research organizational structures better suited to adapt to changing market conditions, product portfolios, and enterprise infrastructures. For this purpose, business processes have become a focal point of organizational research.

1. Within organizational theory, the term *organization* can have both an institutional and an instrumental meaning. While the institutional view describes an organization as a self-contained entity that has a specific structure, the instrumental term denotes the internal structure of such an entity (e. g., the internal organization of a company). American organizational literature is dominated by the institutional notion of organization. For example, DESSLER defines organizations as: "[...] purposeful social units [that] consist of people who carry out differentiated tasks which are coordinated to contribute to the organization's goals." Dessler (1986), p. 6.

   German organizational literature focuses primarily on the instrumental meaning of the term "organization". Following this approach, a distinction between the functional and configurative organization can be identified. See, e. g., Schreyögg (1997). The functional organization treats organization as a managerial function, i. e., the design and implementation of efficient structures in order to support the goals of the enterprise. This functional approach is performed after the initial stage of goal-setting and planning. The configurative approach, mainly based on the works of KOSIOL, treats the design of an organizational structure as the ultimate initial task, which determines or influences all subsequent activities. Planning is executed within the boundaries set within this initial configuration. See, e. g., Kosiol (1978).
2. Refer to, e. g., Lehmann (1992), p. 1539.
3. See Fayol (1949).
4. See Taylor (1947).
5. Typical characteristics of tayloristic organizational structures include a high degree of separation between tasks, the functional integration of similar tasks into larger organizational units, and a strong separation between dispositive and operational work. Compare Adam (1998), pp. 25ff., for a thorough discussion see, e. g., Sawalha (2000); Kugeler (2001).

The alignment of organizational structures with business processes has been discussed in the organizational literature as early as the 1930s.[6] Authors such as NORDSIECK and HENNING created the distinction between the static structure of the corporate organization (*Aufbauorganisation*) and the organization's processes (*Ablauforganisation*).[7] This separation has led to a duality within the field of organizational research, found mainly in the German literature. Among American authors, CHAPPLE and SAYLES are the most notable early proponents of process orientation.[8]

Despite this early interest in the topic, the process-oriented structuring of organizations did not gain acceptance in corporate practice until the works of PORTER[9], DAVENPORT[10], HARRINGTON[11], and most notably HAMMER and CHAMPY[12] led to an increasing interest in process concepts and their implementation.[13] Today, the creation of process-oriented organizational structures is widely seen as a suitable way to overcome coordination problems between functional units, which may result in long cycle times, low product quality, and redundant task fulfillment.[14]

Despite strong interest, implementing process-oriented structures has proven difficult for many companies.[15] Some of the reasons for these difficulties are existing information technology infrastructures, which support functional organizations and hinder the transition toward process-oriented structures.[16]

Workflow management systems (also known as Business Process Management Systems) address this problem. They support the execution of business processes through the automated coordination of activities and resources according to a formally defined model of the business process (the workflow model).[17] The use of workflow technology as a central building block of modern information system architectures illustrates the increasing importance of this type of application.[18] Workflow technology leverages the

6. Compare, e. g., Nordsieck (1934), p. 76, who defines a process as the treatment of objects.
7. Refer to, e. g., Nordsieck (1931); Nordsieck (1934); Henning (1934); Nordsieck (1972).
8. See, e. g., Chapple, Sayles (1961).
9. Porter (1985).
10. Davenport (1993) and Davenport (1995).
11. Harrington (1991).
12. Hammer, Champy (1993); Hammer (1996).
13. A good overview of process concepts in the literature can be found in Körmeier (1995). Notable German sources for process concepts are Gaitanides (1983) and Scheer (1990).
14. See Nippa (1995a), p. 40ff.
15. For a critical view of reengineering mistakes see, e. g., Davenport (1995), who criticizes the lack of employee-orientation in failed reengineering efforts.
16. Compare Luftman (2003).
17. Compare Georgakopolous, Hornick, Sheth (1995).
18. Compare Leymann, Roller (1996).

value of existing information system infrastructures and helps enterprises in the transition toward a process-oriented organization.[19]

Implementing process concepts within organizations is only one step toward achieving a corporate process focus. In order to reap ongoing benefits from a process-oriented organization, continuous maintenance and control of the business processes is required. Process management deals with the efficient and effective execution of business processes.[20] It consists of the planning, implementation, enactment and controlling of processes, and forms a life-cycle that leads to continuous process improvement. Process management addresses the requirement of companies to stay adaptable to environmental and internal changes. Simultaneously it helps companies realize efficiency gains through the exploitation of cost-effective ways to produce goods and perform services.

Using the Deming Cycle[21] for continuous improvement efforts, the necessary steps to align an organization with its processes can be structured along the four phases plan, do, check, and act (compare figure 1-1).

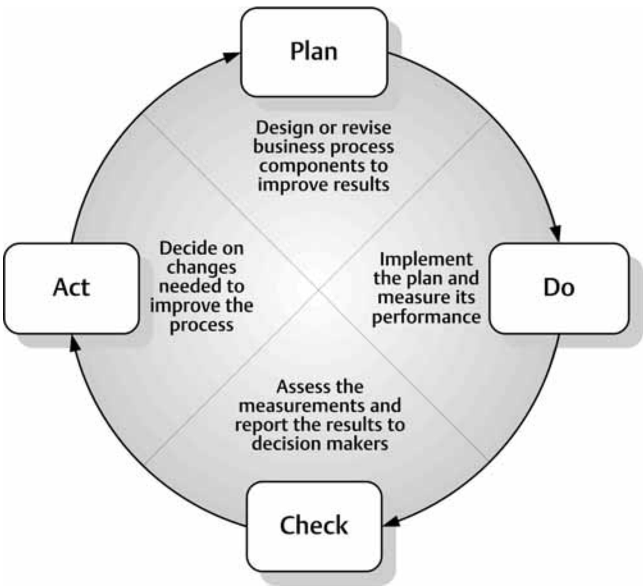

Figure 1-1: Deming Cycle

19. Refer to Plesums (2002).
20. As a preliminary definition, a business process is the logical and temporal order of those activities performed to manipulate an economically relevant object. Refer to, e. g., Becker, Kahn (2002), p. 6; Becker, Schütte (1996), p. 53; Rosemann (1996), p. 9.
21. Compare Deming (1992).

Planning Phase (Plan)

Within the planning phase, organizational processes are identified, modeled and optimized. During this phase, various modeling methods can be employed, such as Petri Net-based approaches or Event-driven Process Chains. Most process engineering approaches focus on this phase. These approaches both align and create modification plans for a company's organizational structures and processes. which then lead to reorganization efforts in the execution phase.

Execution Phase (Do)

Throughout the execution phase, processes are implemented and the organizational structure is realigned to fit these processes. Information systems that support single process steps are implemented, and process participants are trained in the organizational rules and regulations, as well as the use of the supporting infrastructure. Metrics about the process performance are collected during the execution of the new processes.

Evaluation Phase (Check)

Based on the data collected during the execution phase, the effectiveness of the new organization is analyzed in the evaluation phase. Measurements are compared across different processes and organizational units, and relevant results are reported to operative and strategic management units.

Reengineering Phase (Act)

During the reengineering phase, the results of the evaluation phase are reviewed by strategic and operative management units, and the attainment of strategic and operative goals is analyzed. Depending on the performance of the organization, adjustments to the underlying goal structure and measures for the improvement of the current situation are used to create alternative plans. One or more of these plans are chosen for implementation and are handed over to the participants of the planning phase as guidelines for their activities.

The Deming Cycle example illustrates that management of process-oriented organizations requires appropriate measurements in order to verify and ensure the effectiveness of an organization's processes.[22] Process controlling strives to ensure the rationality of the decision making process by

22. "Whatever measures are employed, they must reflect the process as a whole and must be communicated to and used by everyone working on the process. Measures are an enormously important tool for shaping people's attitudes and behaviors; they play a central role in converting unruly groups into disciplined teams.", Hammer (1996), p. 16.

supplying relevant process execution information.[23] One of the core tasks of successful process controlling is the installation and maintenance of an infrastructure that validates operational excellence by providing this necessary information. Workflow management systems record events occurring during the execution of process instances and are thus capable of providing detailed information about the performance of operative processes.[24]

Since the implementation and deployment of a workflow-based application systems is a complex and therefore time-consuming endeavor, it can be assumed that once this kind of architecture has been successfully deployed, many companies resist the urge to apply changes. Despite claims by vendors that the introduction of workflow technology will foster a more flexible, adaptable organization, we believe the opposite is true.[25] The complexity of workflow management projects, however, is only one cause for the reluctant attitude observed toward change. The non-transparency of cause-effect relationships that describe the effects of workflow changes on the organizational, technical, or process level, is a more severe cause for this attitude.

This missing transparency can be attributed to the lack of an integrated infrastructure for the gathering and presentation of performance indicators which describe the behavior of a workflow-enabled organization. Such an infrastructure would provide guidance on which parameter adjustments might increase an organization's efficiency. Even though management information systems have been developed since the 1950s[26], very few of them take the business process perspective into account. A notable exception is the recently developed Balanced Scorecard by KAPLAN and NORTON, which explicitly includes a perspective for internal business processes.[27]

The existing criticism of financial performance indicators and cost controlling approaches[28] does not imply that this information is no longer needed to substantiate managerial decisions. The cost-effective allocation of resources as well as the efficient use of financial assets are important for the sustainability of any economic entity. Focusing on financial information

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23. Compare Weber (1999) and the detailed discussion in section 2.4.2 on page 73.
24. Compare McLellan (1995).
25. The inflexibility of current workflow management approaches has been criticized, e. g., by Dourish et al. (1996). The Generalized Process Structure Grammar, on which DOURISH'S system Freeflow is based, is discussed in detail in section 3.5.3 on page 148.
26. A landmark article commonly seen as the origin of modern decision support and management information systems development was the article by LEAVITT and WHISLER "Management in the 1980's", in which the authors argue that decision processes in companies would be automated in the future, leading to a decreasing number of managers. See Leavitt, Whisler (1958).
27. Compare Kaplan, Norton (1993); Kaplan, Norton (1996).
28. Compare Kaplan, Cooper (1997).

alone, however, can lead to strategic managerial myopia and - ultimately - the subsequent failure of the organization.[29]

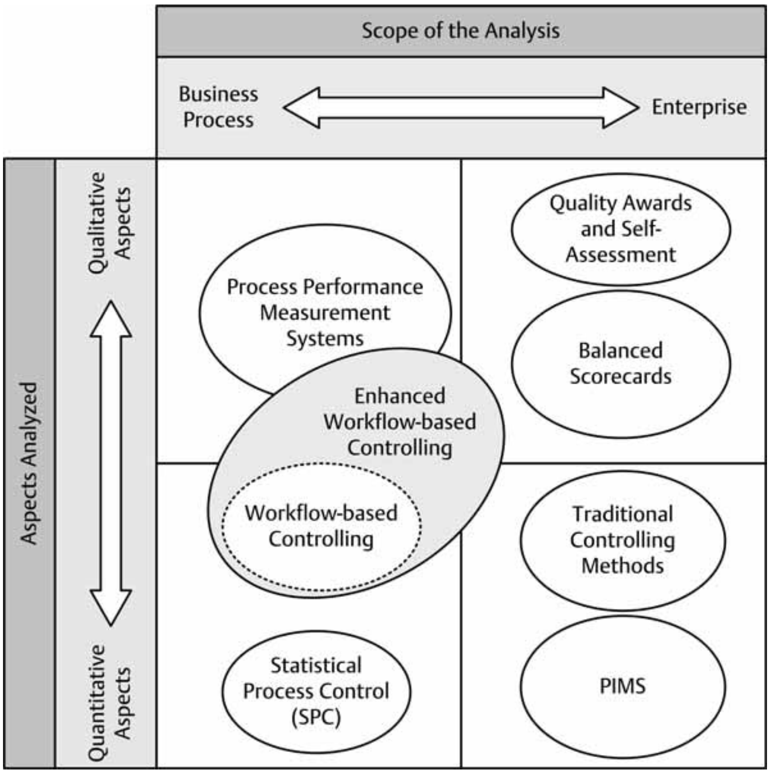
1.2 Goal Statement

The goal of this book is the development of a reference architecture for process information systems that utilize operational information generated by workflow management systems. This controlling infrastructure is designed to enhance traditional enterprise controlling instruments to provide a holistic and process-oriented view of enterprise operations. In order to achieve this goal, it is necessary to have both a methodical discussion about data that can be successfully gathered from a workflow infrastructure, and a conceptual discussion about how this data can be integrated into the management information infrastructure of a company. The purpose of the methodical discussion is the development of a taxonomy of controlling information required by process participants and managers at different levels. The results serve as the basis of an evaluation where this information demand can be met by the information supplied by workflow management systems and where additional information sources are required. The conceptual discussion is intended to develop a design methodology that incorporates controlling information generated by workflow management systems into (new or existing) management information systems.

Workflow-based controlling systems provide companies with the ability to accurately measure the operational performance of business processes. Combined with data warehouse technology and operational business data, complex evaluations can be performed. These evaluations help enterprises to assess their current situation more precisely than could be done through the sole use of traditional (mainly financial) key performance indicators. The increasing maturity of workflow and data warehouse products satisfy the requirements for the implementation of workflow-driven controlling systems.

It should be noted that workflow-based controlling does not replace other enterprise-controlling mechanisms, but enhances them significantly. The positioning of workflow-based controlling in relation to other controlling techniques is shown in figure 1-2. While strategic controlling instruments such as the Balanced Scorecard focus on qualitative aspects of the enterprise, and traditional controlling methods rely on financial information, few techniques exist that place the business process at the center of attention.

29. For a critical discussion of traditional financial controlling measures see Wiese (1999), chapter 3.1.



Adapted from Kueng (1998), pp. 425 ff.

Figure 1-2: Positioning of Workflow-based Controlling

Workflow-based controlling tools that focus entirely on information contained in the audit trail are limited to quantitative analyses of the event-based history of completed processes.

1.3 Relevance of the Subject

Relevance from an organizational perspective

From an organizational perspective, the use of audit trail data for controlling purposes touches upon two areas of an organization: management control, which is based on the new level of information; and controlling, which has to create and maintain a matching infrastructure to manage this information and combine it with complementary data sources.

Management Control

The importance of business process performance measures for the optimization process has been pointed out by HARRINGTON:

"[...] the lack of good white-collar measurements is a major obstacle to improved business processes. [...] if you cannot measure it, you cannot control it. And if you cannot control it, you cannot manage it."[30]

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30. Harrington (1991), p. 164.

Current application system architectures, which are based on workflow technology, enable the collection of process metrics for very little cost. The use of this information to support process-oriented decisions in the management control phase of the management cycle has not been researched in detail yet. One of the biggest unanswered questions deals with the identification of *relevant* process metrics for managers. The analysis of process-related information requirements at different levels of the management system and the juxtaposition of these requirements with information made available by a workflow-based software infrastructure can help shed some light on this question.

Controlling

Audit trail information represents a new form of information that is available to controllers in their function as information suppliers. The usefulness of this kind of information for management purposes has not been assessed so far. An analysis of how audit trail information can enhance existing information sources and which complementary information sources are required, allows enterprise controllers to participate in the design phase of workflow projects. Furthermore, such an analysis ensures that the resulting system architecture delivers the measurements required by established controlling methods.

Relevance from a technical perspective

From a technical perspective, the use of audit trail data for controlling purposes is interesting in three areas: workflow application design, workflow system design, and data warehouses and business intelligence design.

Workflow Application Design

Workflow application designers use workflow management systems as an infrastructure component in the design of complex application systems. They are faced with the necessity to integrate the workflow execution environment with existing application logic and existing data sources. Analyzing the dependencies between application data structures and workflow audit trail records provides workflow application designers with information about how these two data sources can be linked and which application data needs to be accessible from a workflow management system. Also, the development of a metrics framework helps workflow application designers integrate appropriate measuring points in their design, which simplifies the monitoring of the workflow implementation at run time.

Workflow System Design

Workflow vendors use the audit trail mainly as a device for the debugging of workflow applications. While the potential benefits of audit trail analysis for business purposes are known, this potential has been realized by only a few vendors.[31] For example, JABLONSKI and BUSSLER describe a dedicated history perspective within their MOBILE approach. They focus on the use of audit trail data at run time for the identification of past events that impact the current process flow as well as for recovery functions, and point out the use of audit trail information for revision, analysis and reengineering purposes from a business perspective.[32] In the context of production workflow systems, LEYMANN and ROLLER use the term *monitoring* to describe the use of audit trail information to ensure the correct functioning of a workflow implementation. In the same source the authors describe the use of audit trail information in the area of process management without specifying a system architecture for this purpose.[33] A conceptual framework for the integration of workflow audit trail data in controlling applications would provide workflow vendors with guidelines as to which information should be included in a workflow audit trail and which methods should be supported to access this information.

Data Warehousing and Business Intelligence Design-

Providers of management information and decision support systems typically deal with information generated by transaction processing systems. This type of data represents business objects, customers, suppliers, and other entities from the operative system of the company. Audit trail data differs from this information, since it concerns the behavior of the organization and its members, regardless of the business context in which this data was generated.[34] Therefore, both the design of data structures for the efficient storage and retrieval of audit trail data and the combination of audit trail information with related business data are of interest to data warehouse and business intelligence vendors.

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31. Chaffey gives the metrics module of Staffware as an example for workflow-based analysis. Compare Chaffey (1998), pp. 27-28. For a detailed discussion of related work refer to chapter 4.1 on page 175.
32. Compare Jablonski, Bussler (1996), pp. 184-185, pp. 264-267 and p. 307.
33. See Leymann, Roller (2000), pp. 58-60 and pp. 105-111.
34. Compare, e. g., the work by LIST ET AL. on the design of Data Warehouse structures for workflow data. Refer to List et al. (1999) and List et al. (2000).

1.4 Related Work

The application of workflow management technology to the controlling domain has been studied in a number of research projects. The existing approaches can be grouped into three categories: The application of workflow concepts to data warehouse design and operation, the analysis of technical facilities for audit trail generation, and the analysis of workflow audit trail data from an enterprise controlling perspective.

Applying Workflow Concepts to Data Warehouse Design

Sources that use workflow technology for the design of data warehouses aim squarely at the design phase of data warehouse projects. Since the retrieval and transformation of operational data into the data warehouse is a frequent and structured process, it is a prime candidate for workflow automation.

BOUZEGHOUB ET AL. describe the modeling of data warehouse refreshment processes as a workflow.[35] They use an event-driven workflow modeling approach to trigger various parts of the refreshment process either after a timer has expired or after a predefined condition in the data warehouse has occurred. In particular, they distinguish between *client-driven refreshment*, when a user activity causes an update to the data warehouse structure; *source-driven refreshment*, when the changes to the source data of the data warehouses trigger a refreshment process; and *ODS-driven refreshment*, which is triggered by the data warehouse if the content of the operational data store (ODS) is updated.

In his discussion of workflow and data warehouse concepts, PATTERSON identifies several areas in the data warehouse design process that could benefit from the use of workflow technology, such as the handling of update anomaly problems.[36]

Technical Facilities for Audit Trail Generation

KOKSAL ET AL. discuss the management of audit trail data in the distributed workflow management system Mariflow.[37] The authors focus on technical issues regarding the storage of audit data and the economical design of queries on distributed data sources, but they do not address the business value of process history data.

35. See Bouzeghoub, Fabret, Matulovic-Broqué (1999).
36. See Patterson (1996).
37. See Koksal, Alpinar, Dogac (1998).

MUTH ET AL. present an approach for the tracking of history information in a distributed workflow management system.[38] Within the prototype Mentor-lite, data about current and past workflow instances are kept in a temporal database to be queried either at run time or for ex-post analyses.

Analysis of Audit Trail Data

The analysis of audit trail data has been researched for both technical and economical purposes. AGRAWAL ET AL. use data mining techniques to create workflow models from audit trail data.[39] This project uses data from the ad-hoc execution of processes to subsequently identify common rules and procedures and to create workflow models using a bottom-up approach. The authors have tested their approach against artificial data sets and audit trail data from a live workflow installation. A similar approach has been published by VAN DER AALST ET AL.[40] The practical use of the methodology presented, however, requires the existence of a flexible workflow tool which records processes while they are being created on the fly. Despite an obvious demand for such a tool, the current workflow software market is lacking products with this kind of execution flexibility.

A number of publications focus on the ex-post analysis of workflow audit trail data with methods transferred from enterprise controlling.[41] The controlling of processes using workflow audit trail data has been discussed in the German literature to some extent, for example in the works of DERZTELER[42], KUENG and KRAHN[43], RAUFER[44], ROSEMANN ET AL.[45], and WEISS[46]. A number of English sources dealing with this topic can be identified as well, for example KUENG[47], LIST ET AL.[48], MCGREGOR,[49] MCLELLAN[50], ZUR MUEHLEN and ROSEMANN[51]. These sources are discussed in more detail in chapter 4.

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38. See Muth, Weissenfels, Gillmann, Weikum (1999).
39. See Agrawal, Gunopulos, Leymann (1998). The proposed concept of inductive model generation has been patented by IBM, refer to Agrawal, Leymann, Roller (1998).
40. See van der Aalst et al. (2003), and http://www.processmining.org
41. These papers can be divided into conceptual works on the general collection and evaluation of audit trail data, see, e. g., McLellan (1996); List et al. (2001); zur Muehlen (2000), and zur Muehlen (2001), as well as papers that deal with specific prototypes, e. g., Raufer (1997); Weiß (1998); Derszteler (2000), and zur Muehlen, Rosemann (2000).
42. See Derszteler (2000).
43. Compare Kueng, Krahn (2000).
44. Compare Raufer (1997).
45. Compare Rosemann, Denecke, Püttmann (1996).
46. Compare Weiß (1998); Weiß (1999).
47. Compare Kueng (1998); Kueng, Krahn (1999); Kueng (2000)
48. See List, Schiefer, Tjoa, Quirchmayr (1999); List, Schiefer, Bruckner (2001).
49. Compare McGregor (2002); McGregor, Edwards (2001).
50. See McLellan (1996).
51. See zur Muehlen, Rosemann (2000).

1.5 Scientific Positioning

Any scientific work that deals with the development of conceptual entities, such as models, procedures or theories, requires a thorough explanation of the underlying assumptions regarding real world observables and the treatment of these assumptions. For the reader to best understand and evaluate the approach taken and views expressed in this book, the underlying assumptions need to be made clear. This allows criticism of both the work performed and the views presented.[52] In the foundation of a scientific work a critical reflection of the assumptions made and the clarity of the argumentation are the most critical requirement. In particular, these assumptions deal with the question whether a reality exists independent of an observer, and whether the spatio-temporal objects contained in such a reality can be observed independent of the individual observer.

A central aim of this book is the construction of models (describing both data structures and processes) of an object system (the corporate environment or the technical infrastructure within this environment), which is part of a universe of discourse (the economic and technical environment). On the one hand, the scientific positioning is meant to illustrate the concepts underlying the models and procedures developed in this book (i. e., against which concepts these models and procedures can be tested). On the other hand, this positioning is necessary to illustrate the development process that lead to the models and procedures presented in this book (i. e., what are the building blocks of the models and procedures).

For the reasons given above, the two questions discussed in the next section are whether the elements contained in the universe of discourse are based on the existence of an objective reality (ontological question[53]) and whether this objective reality can be perceived in a subject-independent way (epistemological question[54]). The answer to the epistemological question

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52. Compare Schütte (1998), p. 13.

53. The distinction between the terms ontology (from Greek *ontos*, existence and *logos*, teachings) and metaphysics (from Greek *meta*, [the books] about and *physica*, physics) in the German and Anglo-American philosophical literature is not always clear. For example, AUDI uses both terms synonymous (Audi (1999), p. 563 and p. 631). Metaphysics is generally defined as the investigation of the nature, constitution, and structure of reality. See Butchvarov (metaphysics) (1999), p. 563; similar Mittelstraß (Metaphysik) (1995), p. 871. A distinct positioning of ontology and metaphysics is given by Schwemmer (1995), pp. 1077-1079. According to SCHWEMMER, the first use of the word ontology was the denomination of the philosophia prima (the fist part of ARISTOTELES' theoretical philosophy), thus ontology can be perceived as the successor to metaphysics. The German philosopher C. WOLFF (*1679 - †1754) introduced the distinction between the general metaphics (metaphysica generalis) which equals ontology and special metaphysics (metaphysica specialis). In this sense, ontology is the part of metaphysics dealing with questions of existence and reality, while special metaphyics subsumes rational theology, rational cosmology and rational psychology. While there exist notions of ontology that are separate from the general metaphysics (e. g. QUINE'S notion of ontological commitment), we follow the use of ontology as a synonym of general metaphysics in this book.

determines whether the concepts presented in this work can be verified on a subject-independent basis, whereas the answer to the ontological question determines whether the truthfulness of the concepts presented in this book can be determined objectively by comparing them to real world objects.

The philosophy of science offers various, fundamentally different views based on the answers to the questions stated above. For both the ontological as well as the epistemological question, idealistic and realistic positions can be distinguished. While an ontological realist accepts the notion of an objective reality (i. e. objects exist regardless of their recognition by an observer), the ontological idealist (or metaphysical anti-realist) refutes such a concept.[55] Similarly, while an epistemological realist claims that reality can be observed as such and therefore objective knowledge is possible, the epistemological idealist denies this idea and states instead that knowledge always depends on the observing mind. These views lead to three differing positions, as depicted in table 1-1 (the combination of ontological idealism with epistemological realism is not possible, since it is impossible to claim a mind-independent observation of a world-in-itself, if the existence of this world-in-itself is refuted).[56]

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54. Epistemology denotes the study of "(a) the defining features, (b) the substantive conditions or sources, and (c) the limits of knowledge and justification." see Moser (1999), p. 273.

55. Ontological (or metaphysical) realism is founded on the belief that "(a) there are real objects [...] (b) they exist independently of our experience or our knowledge of them and (c) they have properties and enter into relations independently of the concepts with which we understand them." Butchvarov (metaphysical realism) (1999), p. 562. While ontological idealism only denies the existence of material objects, not the existence of other mind-independent spatio-temporal concepts (such as minds, states, words etc.), metaphysical anti-realism rejects one or more of the three basic assumptions of metaphysical realism.

The discussion about the existence of real world objects leads to three different metaphysical world views. While metaphysical materialists accept the existence of material entities, metaphysical idealists only accept non-material (i. e. mental) entities, such as minds and their states. The existence of both types of objects is accepted by metaphysical dualists. See Butchvarov (metaphysics) (1999), p. 563.

56. See Vering (2002), p. 8. An extreme form of epistemological idealism is the skepticism found, e. g., in social constructivism. Epistemological skeptics do not necessarily deny the existence of an objective reality, but they claim this world-in-itself is unknowable. See, e. g., Bird (2000), p. 137.

	ontological realist or metaphysical realist	**ontological idealist or metaphysical anti-realist**
epistemological realist	A real world exists; it can be observed independent of the mind of the observer	Not possible
epistemological idealist	A real world exists; it cannot be observed independent of the mind of the observer	A real world does not exist; thus all observations depend on the mind of the observer

Table 1-1: Fundamental Ontological and Epistemological Positions

Based on these fundamental positions, the philosophy of science has developed several – partially conflicting – positions. The main philosophical positions for scientific work in the area of information systems are critical rationalism, and various forms of constructivism, which can be understood as counter-positions.[57] The positioning that applies to the statements of this book is a radical constructivism with regard to the understanding of reality, and a methodical constructivism with regard to the way how theories are developed and communicated. The effects of this positioning on the results presented in this book are discussed below. A deeper discussion of other philosophical standpoints follows.

Rationalism is based on the belief that reason is the primary way of acquiring knowledge, as opposed to the sensory knowledge acquisition which forms the basis for empiricist positions.[58] The critical rationalism, found predominantly in the works of POPPER and ALBERT, is based on an idealistic ontological view (i. e., there exists a world-in-itself).[59] Theories can be measured against this real world, but, as POPPER points out, it is impossible to prove a theory, but it is possible to disprove it through falsification.[60]

Constructivist scientific theory is based on the epistemological belief that the perceived reality is the result of a construction process by an observing subject.[61] This does not necessarily deny the existence of a real world, it merely indicates that the real world – should it exist – cannot be perceived in an objective way. VON FOERSTER gives various examples of perceptions that are not founded on the existence of real objects.[62] This constructivist belief

57. A good juxtaposition of these positions can be found in Schütte (1998), pp. 13-34.
58. See, e. g., Garber (1999), p. 771.
59. See, e. g., Albert (1985); Popper (1989).
60. See Popper (1989), p. 8, where he states that the truthfulness of theories cannot be proved by their validation (i. e., a valid theory is not necessarily true), and pp. 14-17: “an empirical-scientific system has to be able to fail due to experience.”
61. For an introduction to the constructivist world view see von Foerster (1981), pp. 288ff. where he pointedly writes: “the environment as we perceive it is our invention.” This constructivist view is an opposite extreme to the objectivist viewpoint that knowledge is based on the stable properties of objects in a real world. Objectivists claim that knowledge produced by the analysis of the real world is external to the knower and thus transferable by building appropriate models of the real world.

is fueled by the anatomy of the human sensory system. The reception of optical and acoustic signals as well as other stimuli results in nerve cell responses. These responses do not encode the nature of the source signal (i. e., the quality of the signal), but merely indicate the strength of the sensation, which manifests itself in the amplitude of the electrical signal generated by the cells (i. e., the quantity of the signal).[63] Consequently, the synapses of the brain receive similar electrical signals regardless of the source of these signals. Depending upon the region of the brain that serves as the recipient, these electrical signals lead to the sensory experiences that we associate with "seeing", "hearing", "feeling", et cetera. The brain in itself does not possess a direct link to the outside world; it instead computes our perception of the outside world through the processing of the electric charges received by the synapses.[64] The cognitive process results in the generation of new stimuli, which in turn are received and processed by the brain. This leads to a recursive process of cognition as a series of computations. Following this concept, we arrive at an understanding of the brain as an autonomous, self-referential system that can be influenced by the outside world.[65]

Within the constructivist area of philosophy, radical and methodical constructivism can be distinguished.[66] The concept of radical constructivism is based on the works of VON GLASERSFELD.[67] A central theme of radical constructivists is the (almost) complete omission of ontological statements, since the reality that concepts and theories refer to is the subjective reality constructed by the modeler.[68] VON GLASERSFELD emphasizes this point by explaining why radical constructivism is radical (and not extreme): "Because it breaks with convention and develops a theory of knowledge in which

62. See von Foerster (1981) and the examples given there.

63. Compare von Foerster (1981), pp. 292ff.

64. VON FOERSTER illustrates this concept by rephrasing the definition of *cognition* from "computing a reality" over "computing descriptions of a reality" over "computing descriptions of descriptions" to the final statement "cognition = computation of computations". Von Foerster (1981), pp. 292ff.

65. Compare Vering (2002), p. 10.

66. There are a significant number of other constructivist approaches, such as social, physical, evolutionary, post modern as well as information-processing constructivism. As ERNEST points out: "There are as many varieties of constructivism as there are researchers." Ernest (1995), p.459. The differences between these approaches are mainly with regard to the question how knowledge is constructed. While the radical constructivism sees knowledge restricted to the mind of a single subject, social constructivism claims that scientific knowledge does not arise within individuals but is socially constituted. See Riegler (2001), footnote 1.

67. See, e. g., von Glasersfeld (1984); von Glasersfeld (1995); von Glasersfeld (2001); Riegler (2001).

68. Ontological statements are used to a small extent to explain modeling frameworks. The system theoretic view discussed in chapter 2 is based on the existence of systems, and the existence of these systems is explicitly stated, e. g., by Luhmann (1991), p. 31: "There are self-referential systems. [...] There are systems with the ability to create relationships with themselves and to differentiate these relationships from those relationships they have with their environment." The statement "*there are systems*" is an ontological statement in this context.

knowledge does not reflect an objective, ontological reality but exclusively an ordering and organization of a world constituted by our experience."[69]

A constructivist world view leads to subject-dependent cognitions that cannot be verified or falsified against an outside reality. Due to the unknowability of reality, an empirical verification of theoretical concepts is impossible. VON GLASERSFELD replaces the concept of verifiability with the notion of viability: "To the constructivist, concepts, models, theories, and so on are viable if they prove adequate in the contexts in which they were created."[70] In order not to arrive at an absolute relativism, where every model constructed is as valid as any other model, criteria are necessary to select a "fitting" model over other, competing models. Two distinct approaches to arrive at a valuation of constructivist theories are coherence and consensus. On an individual basis, coherence describes the agreement between different cognitive patterns within one subject's brain, while consensus describes the agreement between the cognitive patterns of several subjects.[71] In order to communicate constructivist theories or concepts among several subjects, a concept developed by one subject has to be reconstructed or comprehended by the other subjects.

The inter-subjective communication of theoretical concepts is one of the main work areas of the methodical constructivist movement, founded on the works of the Erlangen School of philosophy by KAMLAH and LORENZEN.[72] The movement is based on the notion of language critique, which seeks the development of an inter-subjective scientific language that serves as the basis of scientific discourse. Therefore, the focus of methodical constructivism is the development of a viable procedure to construct scientific knowledge and to communicate this knowledge among peers.

In order to establish a common language linking the author and his intended audience, the creation of a common terminology is necessary. Through discourse, agreement about basic terms as well as rules for abstraction and concept-building has to be achieved. This ortho-language consists of basic predicates whose meaning is understood in the same way by all sub-

69. Von Glasersfeld (1984), p. 24, juxtaposes the words "match" and "fit" to illustrate the difference between metaphysical realism and constructivism. To illustrate our limited access to reality, he uses the example of a lock and key. While a certain key unlocks the lock (it "fits"), it does not reveal the capacities of the lock (e. g., if there are different keys that also "fit" this particular lock).

70. Von Glasersfeld (1995), p. 7.

71. Compare Heylighen (2001). Consensus as the basis for concept validation ultimately leads to social constructivism, see footnote 65 on page 15.

72. Because of this, the methodical constructivism is sometimes called *Erlanger Konstruktivismus.* See Kamlah, Lorenzen, Robinson (1984); Lorenzen (1987). For a discussion of the application of methodical constructivist thoughts on the design on formal workflow modeling languages see Messer (1999), pp. 104 ff.

jects involved.[73] Theories are built and explained step-by-step using agreed-upon terms of the ortho-language. Inter-subjective comprehensibility is therefore ensured. This way, reconstructed theories can be presented in a comprehensible way to well-meaning and qualified subjects.[74]

Based on the statements above, the positioning of this book is as follows: Regarding the recognizability of real world phenomena, the author follows a radical constructivist approach. This follows from the fact that a business process is a *logical* ordering of activities. Thus it is a theoretical construct that by nature cannot be observed in the real world. From a critical rationalist view, business processes could be observed as the sum of their instantiations. Since all that can be observed are the individual actions of process participants, the process as a whole has to be constructed by the observer through abstraction and generalization. It should be noted that we do not refute the existence of a world-in-itself (i. e., a reality), but whether this reality exists or not does not have an impact on the concepts discussed in this book.

As for the process of modeling and theory-building, we follow the methodical constructivist approach of the Erlangen School. Using a basic set of terms introduced in chapters 2 and 3, the models and theories constructed in this book should be accessible to any well-meaning and qualified subject. The consequences of this position are as follows:[75]

- An objective perception of a subject-independent reality is impossible. Observations, deductions, inductions and subsequent statements are based on a subject-dependent construction of reality. Therefore, a validation of the statements given in this book against an objective reality is not possible. Instead, the viability of the statements can be tested by judging their “fit” into the constructed reality.
- The subjects of this book are organizational processes and the opportunities to manage and control them with the help of an information system. An organizational process is a conceptual entity. Unlike a

73. It should be noted that the Erlangen School relies on a given consensus about elementary situations (*Elementarsituationen des lebensweltlichen Erfahrens*) and their terms. If no consensus is presupposed, the deductive explanation of a certain word’s meaning leads to the problem of Fries’ trilemma (*Münchhausen-Trilemma*). According to this trilemma, the deductive search for an ultimate explanation leads either to an infinite regress, because every term that is used for explanation can be questioned in turn, a vicious circle, because the explanation uses terms that have been questioned before, or a dogmatic decision to suspend the procedure. See Mittelstraß (Münchhausen-Trilemma) (1995), pp. 945-946 and Schütte (1997), pp. 33-34.

74. The property of well-meaningness is illustrated in POPPER’S assertion: “No rational argument will have a rational effect on a man who does not want to adopt a rational attitude.” Popper (1947), p. 231.

75. For a similar discussion of consequences compare Vering (2002), p. 12-13 and Meise (2000), p. 7-8.

material object a process has no physical manifestation, other than (in some instances) the output of the process. Therefore, the representation of a process in terms of a (formal) model is a theoretical construct, whose features cannot be tested or validated against the features of objectively perceivable "real world" entities.

- An objective measure for the quality of the theories presented in this book cannot be given. The goal of this book is instead the construction of inter-subjective comprehensible models and theories, which can be evaluated by a group of well-meaning and qualified subjects. This relates, for example, to the question of which metrics should be used to determine the efficiency of a given process.
- Due to the nature of constructivist perception, the same environmental situation can be observed and interpreted differently by different subjects. In the context of process controlling, this means that given the same values of the same set of parameters, different subjects may arrive at different conclusions.
- The problem of inter-subjectivity is evident with regard to linguistic terms and expressions. In order to achieve a similar understanding of the meaning of the basic terms, an initial discourse is necessary. This discourse does not need to be complete and exact, but it has to fit the situation in order to avoid an overly complex formal procedure.
- The development of a terminological foundation is especially important as this book is positioned at the junction of enterprise controlling and information system design. In order to create models and theories that are meaningful for both domains, a common understanding of central terms has to be established, and potential homonym– and synonym–conflicts have to be eliminated.[76]

1.6 Procedure Model

The goal of scientific work typically involves the finding of explanations for certain phenomena[77] or the formulation of recommendations for actions. The discipline of information systems follows this separation by pursuing both prescriptive and descriptive research approaches.[78] While prescriptive information systems research aims at the development and formu-

76. For a deeper discussion of homonym and synonym conflicts in multi-domain environments refer to Rosemann (1996), pp. 187-189.

77. Kim points out that "Just about anything can be the object of explanation: A concept, a rule, the meaning of a word, the point of a chess move, the structure of a novel." Kim (1999), p. 298.

78. Refer to Becker (1995), p. 133ff.

lation of design rules and guidelines for information technology and its organizational deployment, descriptive information systems research works to explain organizational and technological phenomena. For each of these approaches methodical goals and functional goals can be distinguished. Information systems research pursuing functional goals aims at the (descriptive or prescriptive) development of information technology and its applications within a particular industry (e. g., the retailing industry or the manufacturing domain). Following methodical goals, information system research aims at the development of domain-independent methods and techniques for the efficient development and application of information technology in business scenarios.

In order to deliver a meaningful contribution to the field of information systems, any information systems research has to generate results within this portfolio. The goal of this book is the development of design methods for process information systems based on information generated by workflow management systems. Therefore, the focus of this book is the methodical goal of information systems research, which is pursued using both descriptive and prescriptive approaches. The central goals of this book, shown in table 1-2, are positioned in the context of this portfolio.

Based on the analysis of the goals and functions of process management and process controlling, the role of process controlling in the context of other enterprise controlling functions is analyzed. Parallel to this, the support of process organizations through workflow management technology is researched, and the quality of controlling information supplied by workflow management systems is assessed.

The results of these analyses lead to the prescriptive development of an information system architecture for the purpose of workflow-based process controlling. Both methodical and architectural aspects are discussed and a reference meta model for workflow-based controlling information is developed. The functional goal of this book is the confirmation of the concepts through a case study at an insurance company. Finally, the development of a research prototype based on the reference architecture serves as a feasibility study for the ideas discussed.

	Descriptive Approach	Prescriptive Approach
Methodical Goal	■ Analysis of process management and controlling goals and functions ■ Analysis of workflow technology support for process organizations ■ Analysis of controlling information supplied by workflow management systems	■ Development of a reference meta model for workflow audit trail information ■ Development of a data model for the integration of workflow audit trail data in process controlling systems ■ Implementation of a prototype process controlling system
Domain-Specific Goal	■ Description of process controlling requirements in an insurance industry case study	

Table 1-2: Positioning of the Book

1.7 Structure of the Book

The book is structured in six chapters. Following this introductory chapter, the second chapter discusses the management requirements and methods for process organizations. A system theoretic analysis of organizational functions serves as the basis for the definition of central terms and the introduction of a management framework. Based on this framework, management and controlling of process organizations at the strategic and operational level are discussed. We define process management and controlling, and introduce a life-cycle model for organizational processes and their automation.

Chapter three presents workflow management systems as a technological support platform for the implementation of process-oriented organizations. After a discussion of the history and current status of workflow technology, integration and coordination functions are presented on a conceptual level. Following a review of the current level of standardization for workflow management systems, the development and application of workflow-based application systems is outlined. This discussion leads to the introduction of the concept of workflow-based monitoring and controlling.

Chapter four discusses the use of workflow technology for controlling purposes at the management levels established in chapter two. Following a review of related approaches, we analyze the information supplied through workflow audit trail data and develop a reference meta model of audit trail information. In the next section, we develop a conceptual framework for process controlling based on workflow audit trail data. Beginning with different categories of analysis, we outline the integration of audit trail information in the enterprise controlling infrastructure. Finally, we integrate the information supply framework and analysis perspectives into a cybernetic process controlling framework.

Chapter five illustrates the practical relevance of the previous discussion using a case study from the domain of financial services. Following this section, a prototypical implementation of a process controlling system is presented. The system architecture and the underlying data model are discussed on a conceptual level, and sample evaluation methods are illustrated.

Chapter six reviews the findings of the book and present potential topics for future research. Figure 1-3 shows a graphical representation of the structure of this book.

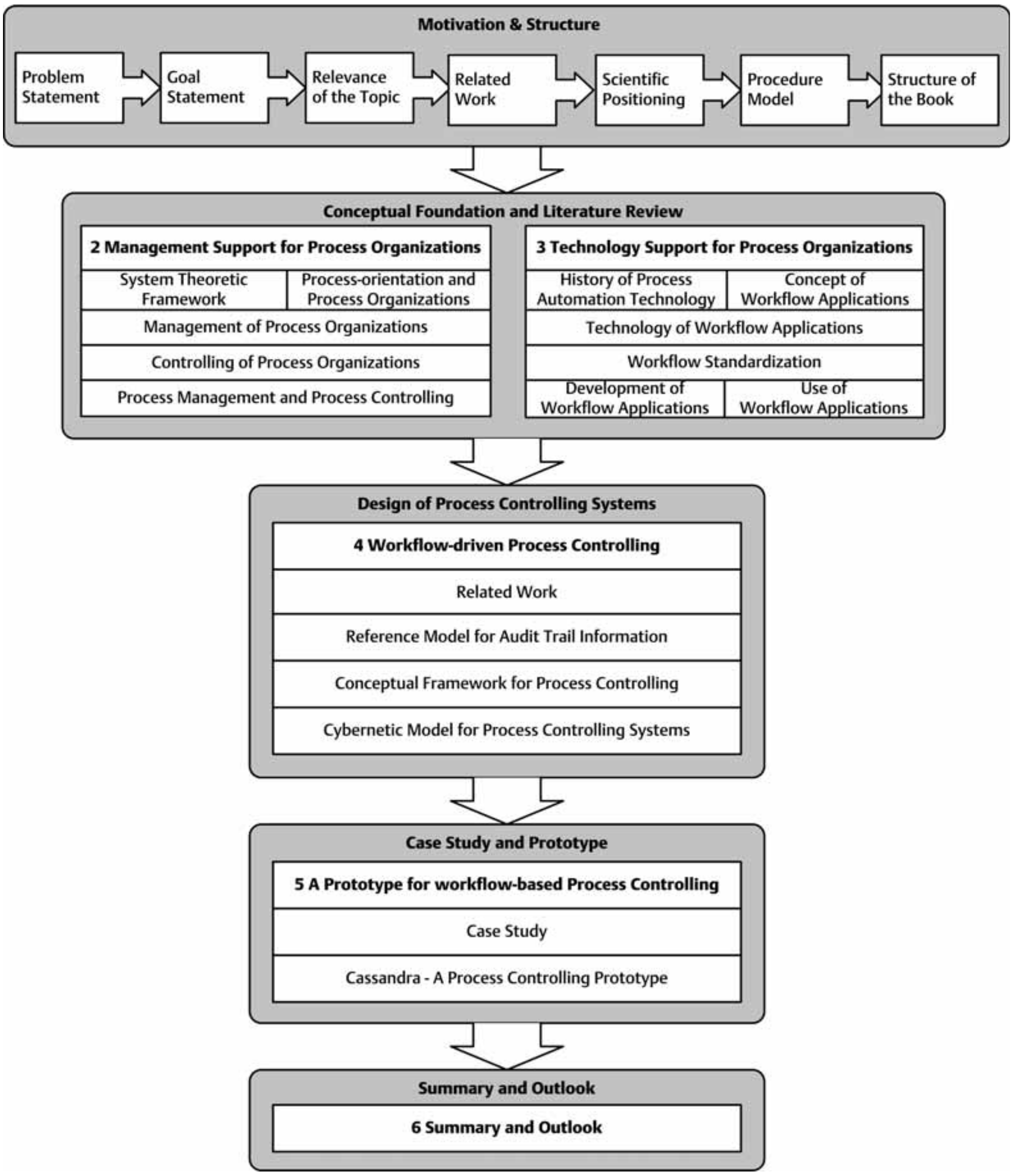

Figure 1-3: Structure of the Book

2 Management Support for Process Organizations

In this chapter we discuss the organizational foundations that contribute to the topic of process monitoring and controlling. Starting from a system theoretic view of organizations we discuss the role of management and control in relation to an organization's processes. In chapter 2.1 we introduce the foundation of system theory that is applied to the analysis of companies in subsequent chapters. Chapter 2.2 provides an overview of processes in organizations, the design of organizations around their processes, and frameworks to describe and analyze these processes. We introduce a taxonomy of business processes and use the ARIS architecture as an example framework for the analysis of business processes. Chapter 2.3 gives an overview of management activities that relate to an organization's processes. In particular, we focus on the differentiation between strategic and operative management, and look at the functions of management control. After defining management control and its activities we use the cybernetic control loop to further specify the activities of management control. Chapter 2.4 examines the management control aspect in more detail by looking at controlling activities in the organization. We differentiate controlling from the field of management accounting and introduce different controlling views from the German business administration literature. Using WEBER'S definition of rational controlling, we focus on the role of controlling in process-oriented organizations. Chapter 2.5 synthesizes the results of the previous chapters and applies them to business processes, setting the scope for the subsequent chapters of this book. We define process management and process controlling, develop a life-cycle of business process management, and position process management and controlling as phases of the overall process life-cycle.

2.1 A System Theoretic Framework for Organizational Analysis

A company, in the broadest sense, creates goods or provides services. In order to achieve this, logistics processes for the sourcing, manufacturing, storage and delivery of these goods and services have to be performed. Input factors, such as other goods and services are consumed or transformed in these processes.[78] These logistics processes are connected with financial processes which involve the raising, appropriation, and investment of funds.[79] Both the flow of goods and the flow of monetary assets form the operative system of the firm. The goal of a firm's operative processes is the creation or use of tangible and intangible goods. (By contrast, the goal of certain governmental processes is the impact on social structures.[80]) In most

78. Compare Küpper (2001), p. 13.
79. Küpper (2001), p. 13.

cases the tasks performed in the operative system and the decision making about aspects of the operative system are performed by different parties. Therefore, the activities of these parties have to be coordinated in order to contribute to the overall goals of the enterprise.

In order to understand the internal structure and behavior of different organizational subsystems and their connections, we need a way to structure and analyze these entities. Typically this is done using abstract representations of actual organizational facts, i. e. models. The term model has a different notion in different scientific disciplines.[81] In this book we base our understanding of the term model on the definition of SCHÜTTE.[82] A *model* is an *artificial construct* designed using a particular *language* (the *modeling language*). It is a representation of an original that is *relevant* at a certain *time* for the purpose of a recipient (the *model user*). The creator and the user of a model may or may not be the same entity. Therefore, the building blocks of a model are an original, the construction process, the model user, a certain time of relevance and a modeling language.

Particularly in the discipline of information systems, a large number of modeling formalisms exist for purposes such as data modeling, process modeling, or organizational modeling. In order to define and compare these different modeling languages, we can use *meta-models.* A meta model is a model that describes the grammar of the modeling language (i. e., the elements that can be used to construct models in the modeling language) and the usage of the grammar (i. e., rules that describe the correct construction of models using the grammatical elements available).[83] A meta model can be expressed in the same language as the modeling language it describes. For instance, a dictionary (meta model) can be written in the same language as the vocabulary it defines (modeling language).[84]

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80. Compare Küpper (2001), p. 13.

81. Refer to Köhler (1975), col. 2702; Lehner (1994), pp. 16f.; Lehner, Hildebrand, Maier (1995), pp. 32f.

82. Refer to Schütte (1998), p. 59 and SCHÜTTE'S extensive discussion of this definition on pp. 40-62.

83. Compare Strahringer (1996), who distinguishes language-oriented meta models such as the one described in the text, and process-oriented meta models that describe the procedure of creating a model using a specific modeling language. For example, while a dictionary explains the vocabulary of a language (i. e., the syntax and semantics of the language elements), a style-guide explains the proper design of sentences and expressions in that language (i. e., the process of creating a model using the language). In this sense, the dictionary contains the language-oriented meta model, while the style-guide contains the process-oriented meta model of the language. For a discussion of both types of meta models compare Holten (1999), pp. 11-18.

84. Note that the meta meta model of the example given could be the instructions for using the dictionary (i. e., the process-oriented meta (meta) model for applying the elements of the (meta) model level). However, this meta meta model would have no impact on the elements at the model level (a sentence in a particular language), because of the change in meta-abstraction (from language-oriented to process-oriented). Compare Strahringer (1996), p. 26; Holten (1999), p. 17.

The system theoretic view of the company offers a framework for the analysis of organizations in whole or in part. Within this book, we use organizational models that are based on the concepts found within system theory.[85] The elements of system theory thus form the basic vocabulary for our modeling language. The following sections provide an overview of the general principles of system theory, and outline, how these concepts relate to the structuring of organizations.

2.1.1 Systems and System Theory

General system theory deals with the description of the structure and behavior of (complex) systems. It is composed of a number of independent scientific movements that originated in the 1940s. Biological system theory, regarded by many as the origin of system theory in general, was founded by the biologist LUDWIG VON BERTALANFFY.[86] NORBERT WIENER used system thinking for the analysis of the information flow within and between systems, and founded the discipline of cybernetics.[87] Simultaneously with WIENER, CLAUDE SHANNON researched the mathematical foundations for the reliable transmission of messages within information systems.[88] His information theory is another example of a system theoretic movement.

A system in its most general form is a set of entities and relationships between these entities.[89] Formally defined a system S consists of a triple (E, R, U) where E contains the entities of the system and R contains the relationships between those entities. Systems can be nested, i. e. the elements of a system can be other systems, forming a hierarchy of systems and sub-systems. From the perspective of a lower-level system, the higher-level systems form the environment. In this case, the subordinate systems are called sub-

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85. Note that we apply SCHÜTTE'S definition of a model using the vocabulary of system theory. This use should be distinguished from e. g. HORVÁTH'S definition of a model: “[Models] are (simplified) images of real or mental systems (e. g. the model of a house, data flow plan of an information system). [...] Only the empirical evaluation shows, whether the results of modeling are a reflection of reality.” Horváth (2001), pp. 101-102. This definition conflicts with the constructivist standpoint outlined in chapter 1. Since reality cannot be observed in an objective way, it is impossible to create an (objective) image of reality. Models are always results of the subjective act of modeling by a modeler. The original from which a model is constructed is the result of individual cognition (i. e., a model in itself). Only the use of an agreed-upon modeling language and the fitness of a model for the purpose of the model user can ensure the usability of a model. Furthermore, HORVÁTH'S definition restricts the use of models to the representation of systems. Since systems are mental constructs in their own right, the term “real [...] systems” is misleading. Compare Schütte (1998), p. 47, especially footnote 49.

86. See von Bertalanffy (1968), pp. 8ff.; Ferstl, Sinz (1993), pp. 11ff.; Hill, Fehlbaum, Ulrich (1994), p. 20; Lehner, Hildebrand, Maier (1995), pp. 44-57; Rosemann (1996), p. 14.

87. Refer to Wiener (1948).

88. Refer to Shannon (1948).

89. ACKOFF defines a system as “a set of interrelated elements. Thus a system is an entity which is composed of at least two elements and a relation that holds between each of its elements and at least one other element in the set. [...] Furthermore, no subset of elements is unrelated to any other subset.” Ackoff (1971), p. 662.

systems, the root system is called super-system. *U* is the world external to the system (*Umwelt*), also called the environment.[90] *E* is also called the universe of *S*, while *R* is the structure or *S*. *E* and *R* are non-empty sets, while the section of *E* and *U* is empty.[91]

Systems can be classified according to different attributes.[92] HILL ET AL. distinguish between openness, complexity and dynamics.[93] If relationships exist between a system element *e* and an element of the environment *u*, a system is called *open* system. Contrary, a *closed* system only contains relationships between the elements of the system itself. The *structural complexity* of a system describes the variety[94] of the elements and relationships within the system (i. e., their structural differences). The total number of (potentially similar) elements and relationships within a system determines the *organizational complexity* of the system.[95]

The *state* of a system is the set of relevant system properties at a given point in time.[96] In particular, a given system can be in different states at the same time, if these states relate to different properties of the system.[97] The rate of change of a system's state determines the dynamics of the system.[98] Accordingly, a *dynamic system* has an inner state that can be changed through inputs and that leads to an output of some sort, while a *static system* does not

90. In the aforementioned case of sub- and super-systems, the super-system constitutes the environment of its sub-systems. Not all sub-systems need to be aware of the existence of all other sub-systems. Instead, a system's environment is usually treated as a black box.

91. Compare Siegwart (1996), p. 191 and the references cited there.

92. A classification of system attributes is provided e. g. by Ackoff (1971), pp. 662-667 and Haberfellner (1974), p. 17.

93. See Hill, Fehlbaum, Ulrich (1994), p. 22ff.

94. Variety is defined as the set of distinguishable elements of a system, or the set of distinguishable states a system can be in. For example, a system containing the elements (a, b, c, c, d, b, a, b, a) has a variety of four, since there are four distinguishable elements (a, b, c, d). Compare Ashby (1956), pp. 121-126.

95. The terms structural and organizational complexity relate to the German terms *Komplexität* and *Kompliziertheit*, respectively. While the proper English translation for Kompliziertheit is complexity, the use of the proper term would confuse the distinction between the two terms, therefore the attributes structural and organizational are added. Within the scientific literature, the distinction between structural and organizational complexity is discussed differently. Bronner (1992), col. 1122, defines the combination of structural and organizational complexity as complexity in the wider sense. Ropohl (1979), pp. 71f., derives the structural complexity of a system from the number of different relationships, while the organizational complexity is determined by the number of different sub-systems. Lehner, Hildebrand and Maier (1995), p. 49, see the dynamics of a system as the source of its complexity. Sinz (1996), p. 127, differentiates between extensional complexity, describing the number of a specific element type, and complexity at the type level, which is a result of the difference between system elements. Also refer to Kruse (1996), p. 28 and p. 34.

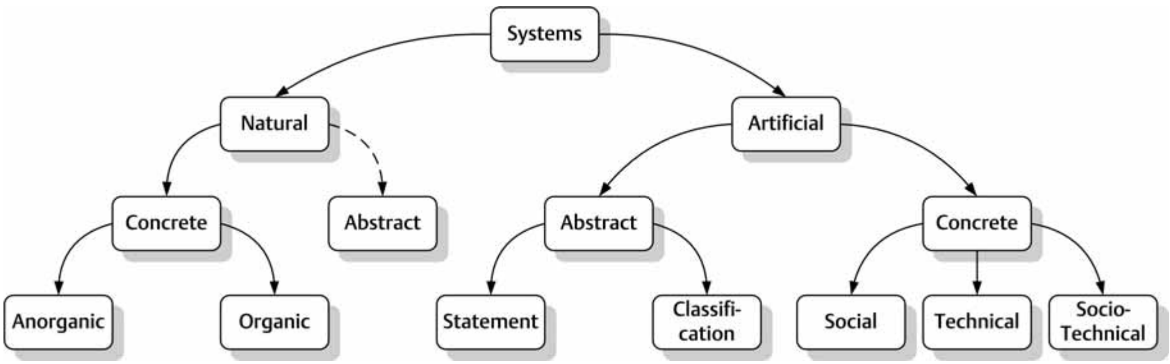
96. Compare Ackoff (1971), p. 662.

97. For example, a convertible car as a mechanical system can be in the state "moving" from the perspective of a traffic observer, while it is in the state "roof closed" from the perspective of an exterior designer.

98. ASHBY defines the state of a system as "any well defined condition or property which can be recognized if it occurs again."Ashby (1956), p. 25. State changes are often induced by an interaction of a system with its environment. ACKOFF consequently defines the environment of a system as a set of elements and properties which can produce a change in the system's state. See Ackoff (1971), pp. 662-663.

exhibit state changes.[99] A special category of dynamic systems are *homeostatic systems,* which are capable of maintaining a specific state in a changing environment through internal adjustment.[100]

HABERFELLNER distinguishes between natural and artificial systems depending on their creator, as well as specific or abstract systems, depending on whether the system is a mental construction or represented through "real" objects (compare figure 2-1).[101]



Source: Compare Haberfellner (1974), p. 17.

Figure 2-1: Taxonomy of System Concepts

The representation of a system can be organized by one of three different system views:[102]

- The *hierarchical system view* focuses on the composition of (super-)systems through other (sub-)systems. There is no limit to the number of system levels that can be nested.[103] The introduction of system hierarchies enables system designers to refine coarse systems (top-down-approach) or to abstract from detailed systems (bottom-up-approach).
- The *functional system view* focuses on the dynamic behavior of a system. A typical view from the functional viewpoint is that of a system as an

99. Compare Hill, Fehlbaum, Ulrich (1994), p. 23; Lehner, Hildebrand, Maier (1995), p. 50.

100. Compare Ackoff (1971), p. 664. In order to remain stable in a changing environment, a system needs to have as much internal variety as it is exposed to environmentally. This *law of requisite variety* was first stated by ASHBY, see Ashby (1956), pp. 206-208. A homeostatic system is an example of a system, which is capable of maintaining a stable state, also called an equilibrium, refer to Ashby (1956), pp. 82-85.

101. Compare Haberfellner (1974), pp. 16-27. Note that this notion seems to conflict with the world view used within this book. However, the constructivist philosophy simply states that a reality cannot be perceived objectively. Whether such a reality exists is thus not relevant for the evaluation of model quality. From a radical constructivist point of view every system is a construction of the mind and thus an artificial system. For reasons of simplicity, HABERFELLNER'S classification of systems is shown in the original form.

102. Compare e. g.Teubner (1999), p. 14-15 and the references cited there.

103. While a hierarchical system view is a suitable way to abstract from or detail specific parts of a system, a recursive repetition of systems within systems is a way to provide inheritance of system attributes or behavior, comparable to the inheritance concept of object-orientation (compare e. g. Oestereich (1997), pp. 38-41). An example is the viable system model by BEER, which consists of 5 distinct systems in a recursive structure, i. e., the internal composition of the (sub-)systems 1A to 1D consists of the 5 distinct systems on a lower level of recursion. Compare Holten (1999), pp. 142-153 and the references cited there.

opaque entity (i. e., a black-box) that has certain inputs and outputs. The system is fed via its inputs and produces a certain output. It can be either stateful or stateless. In a *stateful* system, the behavior of the system is influenced through inputs. As a typical result, a similar input applied subsequently to such a system may produce a different output than the original input, because the state of the system has changed through the first operation. A *stateless* system does not exhibit this behavior, i. e., the same input will always result in the same output.

- The *structural system view* focuses on the organization of entities and relationships within a system. This view can be built through a functional or a structural analysis. The functional analysis tries to explain the inner workings and behavior of a system (which is observed in the dynamic view). The structural analysis leads to the development of entity clusters whose internal relationships are significantly stronger than relationships between this cluster and its environment.[104] In contrast, the functional analysis leads to abstract entity clusters that can only be distinguished through their functions, but not necessarily through their relationships to other entities.

The three different perspectives on systems are depicted in figure 2-2.

Inherent Dangers of the System View

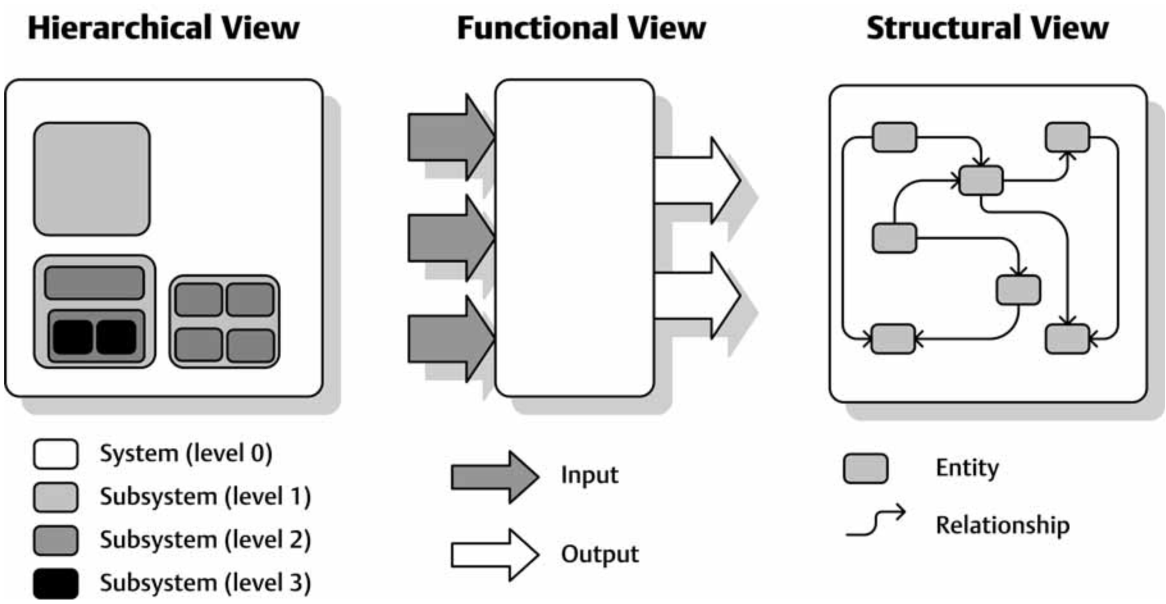
The system theoretic analysis of organization poses certain perils, some of which have been pointed out by HORVÁTH:[105]

- Organizations can be perceived and structured as systems, but they *are* not systems per se. A system view of the enterprise is only a mental framework for further analysis.[106]
- The assumption of teleological behavior is problematic, i. e., the explanation of an element's behavior through the behavior of the surrounding system. This is especially true when the entities of the system exhibit a certain behavior that cannot be attributed to system

104. Compare Teubner (1999), p. 15.

105. Compare Horváth (2002), pp. 104-106. HORVÁTH points out that talking about systems does not provide empirical evidence of real world events (Horváth (2002), p. 105). Horváth's argument can be interpreted in the sense that the structure and behavior of a system (i. e., an abstraction of a more complex underlying entity) does not necessarily have a direct equivalent in the underlying entity (which may also be perceived as a system). One crucial requirement for systems engineering efforts that can be derived from this insight is the incorporation of well-defined quality guidelines for systems design. These guidelines have been proposed by BECKER, ROSEMANN, SCHÜTTE and others as the Guidelines of Modeling (GoM). Compare Becker, Rosemann, Schütte (1995); Becker, Schütte (1996); Becker, Rosemann, von Uthmann (2000). For quality guidelines for reference modeling see Schütte (1998).

106. Horváth (2002), p. 105.



Source: Compare Teubner (1999), p. 14; Seiffert (1992), p. 127.

Figure 2-2: Perspectives on Systems

itself. From a system theoretic perspective, a company is comprised of actors, who exhibit more or less rational behavior, but a generalization of this behavior to the level of the company is problematic.[107]

Advantages of the System View

Advantages of the system theoretic view are mainly related to the reduced complexity of the studied organization through systems engineering[108]:

- Complex corporate relationships can be analyzed more easily. Within the management and controlling aspect of organizational design this means that planning and control activities, information objects and their infrastructure can be segmented and analyzed separately; unrelated parts of the organization do not have to be considered.
- Systems building is helpful for the isolation of interesting system dimensions. Through the exclusion of irrelevant details the organizational complexity of the resulting system is reduced.
- A system view of the organization is a valuable instrument for the design of technical systems that are employed within an organization, such as the information technology infrastructure.

107. Compare Lawrence, Lorsch (1969), p. 2.
108. Compare Horváth (2002), p. 105.

- The view of the organization as a system fosters the analysis of ongoing system changes, therefore it enables the dynamic control and regulation of system aspects.

2.1.2 Companies as Socio-Technical Systems

Organizations, and thus companies can be perceived as socio-technical systems that are goal-oriented, have a specific purpose[109], have relationships to outside entities (i. e., they are open systems), exhibit a significant complexity both in terms of structure and organization, and change within their structure and organization over time (i. e., they are dynamic systems).[110] The constituting characteristic of a company as a system is the (artificial) demarcation between the company and the outside world.[111] Typically this demarcation is based on the specific goals and objectives of the organization.

Organizational Goals and Objectives

Organizations are founded to achieve certain goals and objectives.[112] These goals have a direct impact on the structure and behavior of the organization.[113] In order to achieve these goals, different parts of the organization are specialized on the achievement of individual goals. For example, the task of the human resource staff relates to the system goals in the following way: they are responsible for supplying qualified resources to carry out the tasks within the enterprise, but they are typically not responsible for product goals.

Organizational goals have a controlling function, since they can serve as a benchmark for alternatives within decision processes in the organization.[114] If several choices exist for a particular decision, an evaluation using the organization's goals results in a ranking of alternatives, ultimately increasing the quality of decision making if the best alternative is chosen (i. e., the one contributing most to the goals). An important distinction can be made between the overall goals of the organization (sometimes called enterprise goals) and

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109. Companies are purpose-oriented, because they produce an output, which is in the interest of their environment, e. g. a product that satisfies the needs of customers. In the following sections, the term *organization* is used as a synonym for the terms company and enterprise.

110. Compare for example Hill, Fehlbaum, Ulrich (1994), pp. 20ff; Schulte-Zurhausen (1999), p. 36.

111. Compare Luhmann (1991), pp. 34ff.

112. Compare Staehle (1999), p. 437.

113. Compare Staehle (1999), p. 437-452. He points out that the objectives and the goals of an organization can (and should) be distinguished. While the objectives of an organization represent its contribution to its environment (e. g. society in general), and justify the existence of the organization overall, the goals represent the organizational state or behavior that the organization and its members strive to achieve. See Staehle (1999) p. 438.

114. For an overview of organizational goals see Kugeler (2000), pp. 24-26.

efficiency goals, which relate to the organizational structure and behavior of the organization.[115]

Within this book, *efficiency* is defined as a relational predicate[116] which enables the user to evaluate the design or the result of organizational activities using multi-valued attributes. *Effectiveness* describes the overall suitability of an activity, a structure, etc., to achieve a certain goal or objective.[117] It is mandatory for an organization to be effective in the sense that both its structure and its behavior contribute to the organization's goal. The selection of the appropriate structure and behavior that ensure the most effective pursuit of the goal is the central task of organizational design.

Efficiency goals are a general guideline for organizational design, but they cannot be interpreted as a blueprint for the design of an optimal organizational structure. LAWRENCE and LORSCH have pointed out that the consistency of an organization's internal states and processes with external demands is an indicator for the effectiveness of the organization's behavior.[118] This *contingency theory* states that there is not just one optimal structure for any given organization. Instead, the optimal organizational structure (in the sense of being the most effective and efficient) depends on both the internal state of the organization as well as the conditions of its environment. Additionally, the degree of differentiation inside the organization should reflect the diversity of the organization's environment.[119] This observation is consistent with ASHBY'S *law of requisite variety*, which states that a

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115. The institutional organizational theory, which is dominant in the Anglo-American literature (compare Hill, Fehlbaum, Ulrich (1994), p. 17; Voßbein (1989), p. 9), often fails to make this distinction (compare Kugeler (2000), pp. 29-37 and the references cited there). KUGELER points out that this unified view of organizational goals fails to acknowledge the indirect relationship between organizational measures and (structural) organizational goals, such as maximization of the return on capital invested. An appropriate counter-measure is the definition of efficiency goals, which serve as sub-goals that are positively correlated with the overall goals of the organization and which are instrumental in the evaluation of organizational measures. Compare v. Werder (1999), p. 412.

A typical example for the integrated view of organizational goals is the classification by PERROW, who distinguishes five goal categories:

- *Society goals* address the society in general.
- *Output goals* address the recipients of the organization's output, i. e., its goods and services.
- *System goals* address the structure and behavior of the organization, e. g., growth, stability, profitability.
- *Product goals* address the characteristics of goods or services produced by the organization, e. g., quantity, quality, design etc.
- *Derived goals* address areas outside the primary organizational objectives, e. g., political activities or regional development.

Compare Perrow (1970), p. 135, cited from Staehle (1999), p. 438.

116. The expression *relational predicate* refers to the fact that different types of efficiency can be distinguished, and that two measures of the same efficiency type can be compared directly.

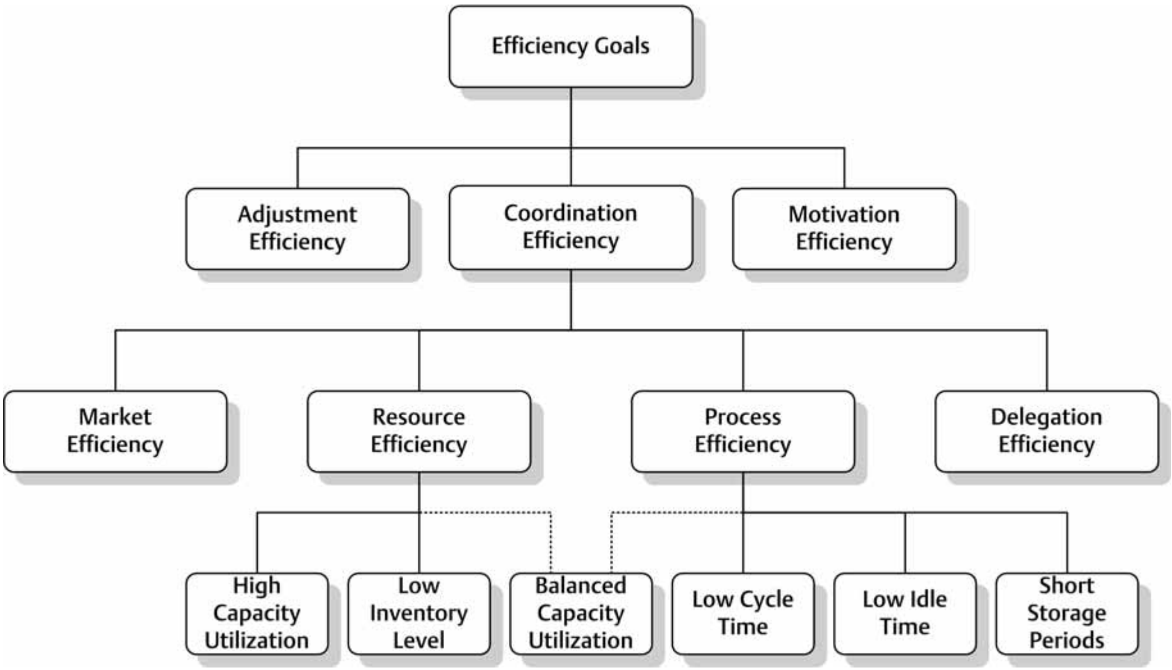
117. Refer to Kugeler (2000), p. 28; Welge, Fessmann (1980), col. 577.

118. See Lawrence, Lorsch (1967), pp. 128-129.

119. See Lawrence, Lorsch (1967), p. 128.

system needs to expose at least as much variety internally as it is exposed to externally, if it wants to maintain a stable state.[120]

The efficiency goals used within this book are based on the works of FRESE, THEUVSEN and v. WERDER.[121] The three organizational efficiency goals are *coordination efficiency*, *motivation efficiency* and *adjustment efficiency*. Furthermore, coordination efficiency can be broken down into the components *resource efficiency*, *process efficiency*, *motivation efficiency* and *delegation efficiency*. Figure 2-3 shows the relationship between these different organizational efficiency goals.



Source: Compare Kugeler (2000), pp. 37-54.

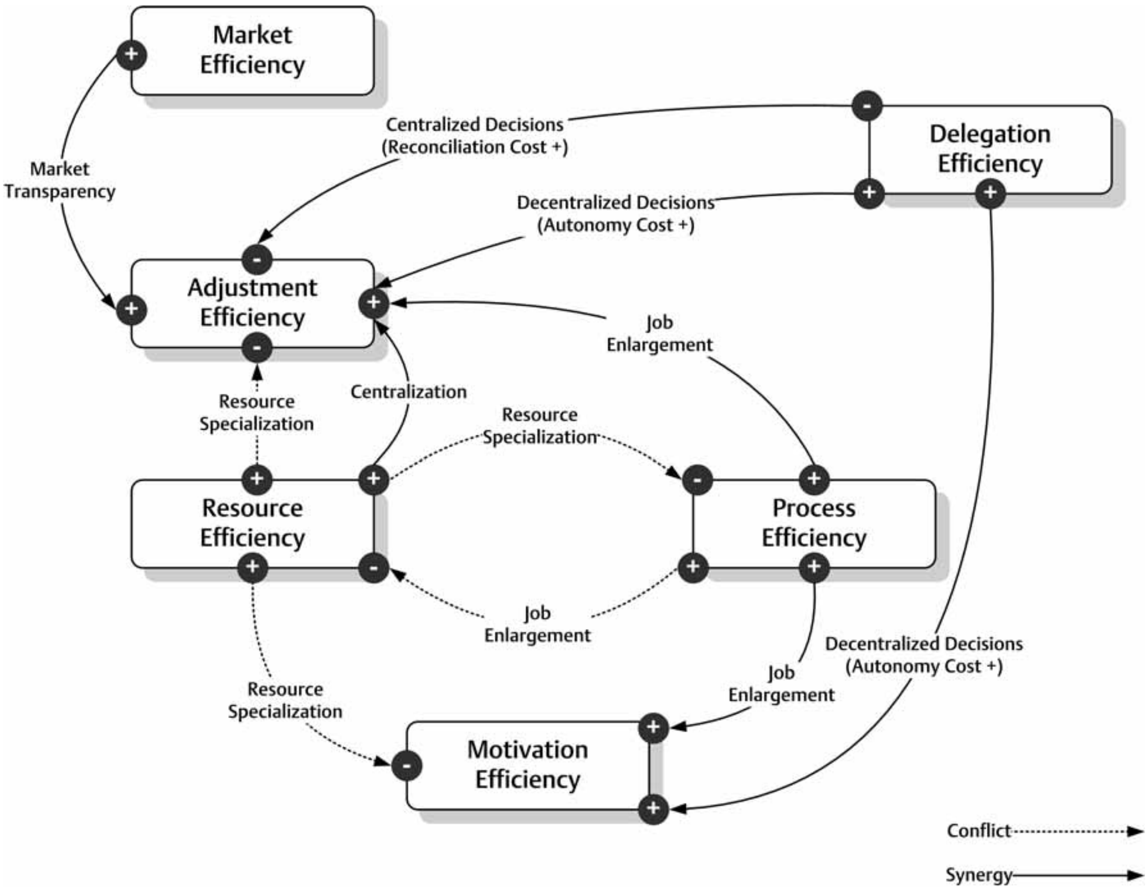
Figure 2-3: Efficiency Goals

Because efficiency goals are not operational in the sense that they cannot be readily measured, they need to be replaced by substitute goals in practice. These substitute goals should have a positive contribution toward the substituted goal. For example, the reduction of cycle and idle times has a positive impact on process efficiency, while a maximization of resource capacity utilized has a positive influence on resource efficiency.

120. See Ashby (1956), pp. 206-208 and the definition of a homeostatic system in footnote 100 on page 27.

121. Compare Frese (2000), pp. 292ff.; Theuvsen (1996).; v. Werder (1998) and v. Werder (1999).

It is important to note that a simultaneous optimization of all efficiency goals is not possible, since measures that improve one type of efficiency often decrease another type of efficiency. Figure 2-4 shows potential synergies and conflicts between efficiency goals.[122]



Source: Compare Kugeler (2000), pp. 55-57.

Figure 2-4: Conflicts and Synergies between Efficiency Goals

Especially problematic is the simultaneous pursuit of process and resource efficiency.[123] On the one hand, a specialization of resources (which increases resource efficiency) increases the number of organizational interfaces in a process and thus has a negative impact on process turnaround times (decreasing process efficiency). On the other hand, the unification of activities through job enlargement (which reduces organizational interfaces and increases process efficiency) has a negative impact on resource efficiency, because the capacity of available resources can only be allocated on a coarse level and this may lead to under-utilized resources.

122. For a thorough discussion of the relationship between efficiency goals compare Kugeler (2000), pp. 55-57.

123. This effect is known as the planning dilemma (*Dilemma der Ablaufplanung*), compare e. g. Gutenberg (1983), p. 216; Adam (1998), p. 549.

Management and Operative System

A common distinction made in the system-theoretic analysis of organizations is the separation of the decision making part of an organization (the management system) from the operating part of the enterprise (the operative system).[124]

The operative system of the enterprise transforms an input stream of goods and services (upstream, supply chain) along the logistics processes to an output stream that is delivered to the customer (downstream, demand chain). In return a flow of monetary values is received through financial processes and passed on to the suppliers as compensation for their goods and services. Each of the logistics and financial processes is encompassed by, and can be represented as an information flow.[125] A financial transaction is represented in terms of invoices, postings and account statements, while a flow of physical products is accompanied by the relevant purchase orders, bill of materials, assembly lists, or delivery notes. The creation, storage, and management of these information objects is the purpose of the operative

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124. Compare e. g. Horváth (2002), p. 112. The roots for this distinctions can be found in TAYLOR'S work on scientific management, which was originally published 1911 (Compare Taylor (1947)). The separation between management and operative system has been criticized by some authors, compare for example Weber (1999), pp. 28-29. This criticism relates to the normative separation of management and operative systems, i. e., there is a lack of arguments why a certain system configuration is chosen as opposed to other possible configurations. In addition, critics of the system approach point out that in reality management and operative functions are closely interwoven in certain areas (e. g., group-concepts in manufacturing). While these arguments are clearly valid (see the discussion in section 2.4.1 on page 70), we use the separation of management and operative functions as a model, i. e., an abstract representation of an organization, to explain the flow of information at different levels of the enterprise.

125. For a thorough discussion of the term information refer to Holten (1999), pp. 71-74 and the references cited there. HOLTEN uses the framework defined by Bode (1997). According to this framework, information can be classified within the dimensions dynamics, novelty, truth, semiotics and carrier. From a *semiotic* perspective, information can either be defined in a syntactic, semantic, or pragmatic way. The syntactical definition describes information as a sequence of characters. The semantic approach defines information as a representation of an object, i. e., information is a sequence of characters with a specific meaning, while the pragmatic approach stresses the purpose of information, i. e., information has to be useful for the preparation of decisions or activities. Information can be perceived as *dynamic* if the process of informing a recipient is addressed. In a static sense, information relates to the precondition and result of the information process. In terms of *novelty*, information can be characterized as unknown to the recipient (individual-subjective view) or unknown within a certain context (objective view). The aspect *truth* distinguishes between truth-dependent information, i. e., information has to be true, or the sender has to believe in the correctness of the information, and truth-independent information, i. e., there is a possibility that the information is incorrect. Finally, information can be either restricted to humans as information carriers, or the storage and transmission of information through technical resources is accepted without altering the characteristics of information.

For the purpose of this book, information is defined as the representation of an object in a particular language. Compare Bode (1997), p. 459. In the context of computer systems, information denotes the technical representation of an object which is stored, manipulated, transmitted, and/or displayed through the computer system. On a conceptual level, information is a higher form of data, which is defined as a sequence of characters. Data has to be distinguished from programs (or applications), which manipulate, store, retrieve, and/or display data. Information relates to economically relevant entities of the company, e. g., an invoice or a customer account, and is context-dependent, i. e., information is bound to a particular purpose.

information system of a company. The operative information system is typically connected to entities outside of the company through cross-enterprise application integration or Business-to-Business integration (CEAI or B2BI). CEAI links the operative information systems of organizations along the supply chain in the support of recurring business transactions, such as order placement, invoicing and offer solicitation.[126] Similar integration exists in the demand chain, where customer self-service applications and order management functions (among others) mirror the supply chain functionality.

The operative system works with a given set of resources and according to a set of rules that are defined by the planning and control system of the organization. In order to be able to regulate the behavior of the operative system, the planning and control system depends on information supplied by the management information system.[127] This system can be fed by information from both in- and outside the company. Internal information can be gathered from the operative information system. This information is typically filtered in order to reduce the amount of detailed information to the level required by the recipient.[128] External information can either originate from suppliers (e. g., shipping dates for supplies), customers (e. g., demographic information), third parties (e. g., credit reports from rating agencies), or government bodies (e. g., tax schedules). The management information system provides information to the entities involved in planning and control processes. This information is used to evaluate alternative strategies, or to control the execution of prior strategic decisions. This part of the management system is traditionally realized through the front-ends of on-line analytical processing systems (OLAP)[129], or through the provisioning of printed reports. More recently, real-time analytics and so-called corporate dashboards are used to provide decision makers with information about operational performance.[130] Based on the results of the planning and control process, the planning and control system exercises influence on the operative system by setting goals, defining procedures, issuing guidelines or similar measures which have to be implemented by the operative system.

126. Examples for these integration efforts are standards such as ebXML, refer to ebXML (2002), Biztalk, see Thatte (2001) or CDIF, refer to EIA (1997) and Flatscher (1997).

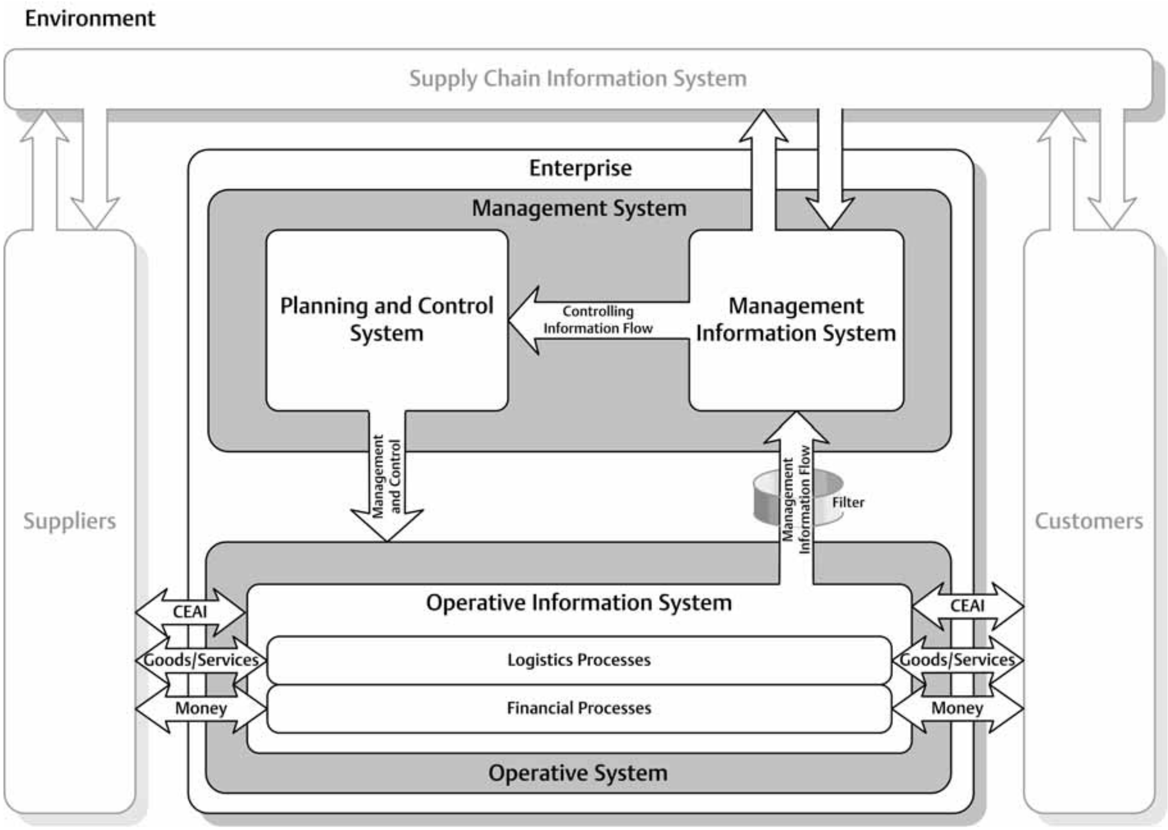
127. The use of information technology for managerial purposes was first described by LEAVITT and WHISLER, compare Leavitt, Whisler (1958). Many of the early systems failed, because the first approaches to provide managers with a view on operative data through Management Information Systems (MIS) were driven by technical progress instead of actual information requirements. Compare Ackoff (1967), who especially criticized the lack of relevance in the information provided by MIS. For a detailed description of the history of management information systems refer to Holten (1999), pp. 29-59.

128. See section 2.3.3 on page 60 for a more detailed discussion of this topic.

129. Refer to Codd, Codd, Salley (1993), who first used the term OLAP to differentiate analytical database use from productive database use.

130. See Houghton et al. (2004) for a case study of corporate dashboards at Western Digital.

Figure 2-5 shows the relationship between the management system and the operative system of the enterprise.[131] It is apparent that the management system impacts the operative system as a whole, but does not selectively change details about the logistics or financial processes. In fact, direct intervention by management constitutes a bypass of organizational control and is discouraged by system theorists.[132] Instead, the management system provides guidelines that have to be implemented by the units of the operative system.



Source: Compare Horváth (2002), p. 117; Wiese (2000), pp. 8-9.

Figure 2-5: System View of the Enterprise

131. The links between the logistics and financial processes are shown bidirectional to include processes such as the handling of returns, recycling, financial discounts, and reimbursements.

132. Compare BEER'S viable system model as an example of organizational management and control structures. Beer (1985); Espejo and Harnden (1989).

2.2 Process-orientation and Process Organizations

2.2.1 Organizational Processes

The operative system of a company is the environment in which the financial,[133] logistics and information processes take place.[134] These processes provide the dynamic structure of the organization, taking goods and services as input factors and transforming them into goods and services as output factors, in order to satisfy customer demands.[135] However, organizational processes are rarely homogeneous entities that are performed by individuals in their entirety. Due to the limited qualitative and quantitative capacity of resources, processes are typically realized through the division of work among different process participants.[136] Companies were able to realize significant economies of scale through the pooling of similar resources and the specialization of functional units.

With an increasing number of functionally specialized process participants, the coordination of the overall process becomes increasingly important, because every hand-off or interface between process participants does not contribute to the original purpose of the process and thus does not support the goals of the organization.[137] The dominance of the functional structuring of organizations with a subsequent planning of the flow of work between the participants has always faced concern[138], but in the 1990s the level of criticism rose to such a level that alternative organizational structures were researched by numerous companies. As a consequence, the process-oriented design of organizations began to attract significant interest. In order to establish a common understanding of the concepts of process-organizations, we take a closer look at the origins of organizational processes in the following section.

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133. It should be noted that in most cases the financial processes are represented as information processes (e. .g. postings from one account to another). Therefore, some authors distinguish between material and information processes, compare e. g. Schulte-Zurhausen (1999), p. 51-52. This perspective will be applied throughout the rest of this book.

134. Certain information processes are also part of the management system, especially the supply of managers with information for decision making processes.

135. Compare Schulte-Zurhausen (1999), p. 49-56.

136. Compare Wiese (2000), p. 24; Schulte-Zurhausen (1999), p. 4.

137. Compare Gaitanides, Scholz, Vrohlings (1994), p. 2.

138. For an early critical view of functional organizations compare, e. g., Nordsieck (1931).

2.2.2 Process Definitions

The central focus of process-oriented organizational design is the flow of work within the organization.[139] Despite the duration of the process discussion in the scientific and popular literature,[140] no common process definition has emerged as of today. To a large extent, the contemporary definitions of business processes originated in the reengineering literature of the 1990s. One of the most prominent process definitions of the 1990s was given by HAMMER and CHAMPY, who focus on the external behavior of a process, noting that a process is:

> *"[...] a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer."*[141]

In a more refined approach, DAVENPORT proposes the following definition:

> *"[...] a process is a structured, measured set of activities designed to produce a specific output for a particular customer or market. It implies a strong emphasis on **how** work is done within an organization, in contrast to a product focus's emphasis on **what**. A process is thus a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action."*[142]

A proponent of Total Quality Management efforts, HARRINGTON, defines a business process in the context of his Business Process Improvement approach as:

> *"[...] any activity or group of activities that takes an input, adds value to it, and provides an output to an internal or external customer. Processes use an organization's resources to provide definitive results."*[143]

More specifically, he distinguishes between this (general) process and more specific production and business process.[144] In a similar definition, SCHMIDT describes a business process as:

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139. Compare Becker, Kahn (2002), p. 6. The German organizational theory outlined the distinction between the organizational structure (*Aufbauorganisation*) and the flow of work (*Ablauforganisation*) for a long time.

140. Compare the notes in section 1.1 on page 1.

141. See Hammer, Champy (1993), pp. 35 ff. In a later publication, HAMMER defines a process equally vague: "We can think of a process as a black box that effects a transformation, taking in certain inputs and turning them into outputs of greater value." Hammer (1996), p. 9.

142. Davenport (1993), p. 5.

143. Harrington (1991), p. 9.

144. Harrington defines a production process as "any process that comes into physical contact with the hardware or software that will be delivered to an external customer [...], up to the point the product is packaged [...]." Harrington (1991), p. 9. He specifically excludes shipping and distribution processes.

"[...] [the] stepwise procedure for transforming some given input into some desired output. The transformation is consuming or using resources. A business process has some form of outcome, i. e. goods or services produced for a customer or customers either outside or inside the enterprise."[145]

The above definitions are similar with regard to the dynamic system view employed, they all stress the input-process-output character of organizational processes. Nevertheless, these definitions are not precise enough to allow for a detailed description of organizational processes using information models. For instance, the definitions do not address the criteria separating different processes within an organization, which is a crucial distinction for the development of organizational process models.[146] In the context of this work, we define a process in the tradition of BECKER and SCHÜTTE as follows:

A *process* is a discrete, holistic, temporal and logical sequence of those activities that are necessary to manipulate an economically relevant object.[147] This object is also called the process object and characterizes the process. Additional supporting objects may become part of the process. Depending on the properties of the process object, we can distinguish between material and information objects.

Business processes are a specific category of processes.[148] A business process is defined as a high level process determined by the overall goals of the enterprise.[149] Business processes contain activities that interface with market partners (i. e., customers, suppliers, or other third parties).

A *workflow* is a specific representation of a process, which is designed in such a way that the formal coordination mechanisms[150] between activities, applications, and process participants can be controlled by an information system, the so-called workflow management system.[151]

145. Compare Schmidt (1998), p. 192.

146. DAVENPORT describes this problem as follows: "Once the processes have been identified at a high level, the boundaries between those processes need to be managed. Because process definition is more art than science, boundaries are arbitrary." Davenport (1993), pp. 30-31.

147. Compare Becker, Schütte (1996), pp. 52-53; Rosemann (1996), p. 9; Becker, Kahn (2002), p. 6.

148. Although many authors use the terms process and business process as synonyms, we feel that the distinction adds value.

149. Compare Nordsieck (1972), col. 8-9, who defines the enterprise process as the stepwise refinement of the enterprise goal.

150. A coordination mechanism is defined as "a construct consisting of a coordinative protocol (an integrated set of procedures and conventions stipulating the articulation of interdependent distributed activities) and an artifact (a permanent symbolic construct) in which the protocol is objectified." Schmidt, Simone (1996). For a detailed discussion refer to section 3.2.3 on page 110.

151. Compare zur Muehlen (1996); Rosemann, zur Muehlen (1998), p. 103. For a thorough discussion of workflows and workflow management systems refer to chapter 3 on page 89.

2.2.3 A Taxonomy of Organizational Processes

Processes in organizations can be grouped into several categories, depending on the nature of the process object. While *logistics processes* are performed with the goal of manipulating a physical object or provisioning a service (e. g., manufacturing a certain product or moving a shipment to a new location), *financial processes* are performed when monetary value is exchanged between two parties. Each of these processes is accompanied by an *information process*, which represents the flow of data in the company's information systems that is caused by the relevant logistics or financial processes.

Figure 2-6 shows a classification schema for processes in form of a morphological box. The left side of the box shows different properties (attributes) of a process, while the right side shows the possible values of these attributes. Besides general process design attributes, the morphological box also contains workflow-relevant attributes. Depending on the value of these attributes, we can identify different requirements for the automation of a process.

Process Participants

The participants of a process can be either human or technical resources, or a combination of both. Within technical resources we can differentiate between hard- and software resources, respectively. Depending on the resource type, the announcement and assignment of pending activities can be performed either automatically (push) or manually (pull). Since the capacity and availability of technical resources can be determined automatically in many cases, automated assignment algorithms can be employed for technical resources, while pull-strategies are more common for human process participants.[152]

Structure

The process and activity structure dimensions determine if the details of a process or activity can be documented prior to their execution. If the structure of processes and activities is known a priori, it can be specified using a formal method. This specification in turn can be interpreted by a workflow management system.

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152. For a review of different work distribution mechanisms compare Hagemeyer et al. (1998) and Hoffman, Löffeler, Schmidt (1999), who analyze the capabilities of workflow management systems in this regard. A more detailed discussion of this aspect can be found in zur Muehlen (2004). The resource modeling aspects of workflow applications are addressed in section 3.5.4 on page 160 in more detail.

<table>
<tr><th>Attribute</th><th colspan="6">Possible Values</th><th></th></tr>
<tr><td rowspan="2">Participants</td><td colspan="2" rowspan="2">Human Resources</td><td colspan="4">Technical Resources</td><td rowspan="6">Workflow Attributes</td></tr>
<tr><td colspan="2">Hardware Resources</td><td colspan="2">Software Resources</td></tr>
<tr><td>Structure</td><td colspan="2">Ad-hoc Activities, Ad-hoc Process</td><td colspan="2">Pre-defined Activites, Ad-hoc Process</td><td colspan="2">Pre-defined Activities, Pre-defined Process</td></tr>
<tr><td>Integration</td><td colspan="2">Process-level (e. g. web services)</td><td colspan="2">Application-level (e. g. programs)</td><td colspan="2">Function-level (e. g. method calls)</td></tr>
<tr><td>Granularity</td><td colspan="3">Objects (e. g. documents)</td><td colspan="3">Attributes (e. g. application fields)</td></tr>
<tr><td>Abstraction</td><td colspan="3">Type</td><td colspan="3">Instance</td></tr>
<tr><td>Process Scope</td><td colspan="3">Within an organization</td><td colspan="3">Between organizations</td><td rowspan="6">Process Design Attributes</td></tr>
<tr><td rowspan="2">Level</td><td colspan="2" rowspan="2">Operative Process</td><td colspan="4">Management Process</td></tr>
<tr><td colspan="2">Operative</td><td colspan="2">Strategic</td></tr>
<tr><td>Validity</td><td colspan="2">As-Is Process</td><td colspan="2">Target Process</td><td colspan="2">Ideal Process</td></tr>
<tr><td>Individuality</td><td colspan="3">Enterprise-specific Process</td><td colspan="3">Reference Process</td></tr>
<tr><td>Recipient</td><td colspan="3">Core Process</td><td colspan="3">Support Process</td></tr>
</table>

Source: Compare Kugeler (2000), p. 16, Becker, zur Muehlen, Gille (2002), p. 42.

Figure 2-6: Classification of Process Attributes

The degree of control flow coordination by the workflow management system is directly related to the level of detail with which the process structure can be specified in advance. The difference between well-defined, rigid process descriptions and ad-hoc, spontaneous collaboration has been discussed in the workflow management domain under the terms *ad-hoc workflow*[153] versus *production workflow*.[154]

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[153]. Compare Plesums (2002), p. 32, who characterizes ad-hoc workflows by the negotiation used to determine the next activity of the process. An prototypical implementation for flexible workflows has been presented by Weske (Flexible) (1997).

[154]. Compare Leymann, Roller (2000).

Ad hoc processes are those processes whose structure is unknown or unknowable until they are executed. This may be because the structure of the process is changing frequently due to reasons outside of the process scope (e. g. customized orders), or because the analysis and documentation of the process structure is regarded as too expensive (e. g. the multi-year assembly of a particle accelerator as described by McClatchey et al.[155]). Activities have an ad-hoc structure if it is unknown or too costly to determine which human, technical, financial, or information resources are required for the execution and completion of the activity.[156] Furthermore, if the conditions that have to be met in order to complete an activity are unknown, this activity is an ad-hoc activity.

Process Scope

The financial and logistics processes of a company stretch from the supply side to the demand side of the organization. The process scope dimension describes the boundaries of a given process.

Processes between organizations (*inter-organizational processes*) are either inbound or outbound processes, which are triggered from outside the company or terminate outside the company borders.[157] Typical examples for these processes are delivery processes on the customer side, and replenishment processes on the supply side. These inter-organizational processes can also be found when one or more activities of a process are executed outside the control sphere of the company, for example, if parts of the process have been outsourced.[158] A typical property of inter-organizational processes is the limitation of control, i.e., parts of the process that reside at the process partner are not manageable by the company itself, but instead constitute a black box.[159] For this reason, autonomous changes to an inter-organizational process have to consider the overall integrity of the process.[160] In

155. Compare McClatchey et al. (1998).

156. The support of unstructured activities in workflow systems has been subject of a number of research projects. Compare, e. g., Blumenthal, Nutt (1995).

157. The two dominant abbreviations for processes that cross company borders are B2B for processes between companies (business-to-business) and B2C for processes between companies and customers (business-to-consumer). To a lesser extent the terms B2G for processes between companies and government agencies (e. g., electronic tax filings) and C2C for consumer-to-consumer processes (e. g., online auctions) are used.

158. Compare Bussler (2002) for a discussion of implementation aspects in business-to-business scenarios.

159. Only very few exceptions from this rule exist, for example if one of the two partners dominates the business relationship and can demand process management from the smaller party. An example for such a relationship is the relationship between car manufacturers and their suppliers. Modern in-line manufacturing cells enable suppliers to finalize the production of their components at the site of the receiving company. Even though the assembly part of the process resides within the domain of the supplier, the car manufacturer can control the process due to the nature of the business relationship.

160. Compare Hayami, Katsumata, Okada (2000).

order to manage this restriction, the integration points between process partners are often formalized using interoperability contracts,[161] which may rely on a standardized protocol. Figure 2-5 illustrates this through the supply chain information system which extends beyond the system boundaries of the company. Information about process performance may be restricted to the part of the process which lies within the scope of an individual company.[162]

Processes within an organization (*intra-organizational processes*) are triggered within the organization (e. g., the design of a new marketing brochure). The company has complete control over the resources involved in these processes and the implementation of the individual activities. KUGELER points out that the majority of corporate processes are inter-organizational processes.[163] This is even more true if we focus on the value-adding processes that directly support corporate goals.

Integration

The integration dimension describes to what extent the internal functions of the application systems involved in the process are accessed.[164] *Process-level integration* refers to a coarse level of application invocation. This level of integration is typically found in inter-organizational processes, when few details about the invoked application systems outside the company boundaries are available.[165]

Application-level integration is found when entire applications are triggered within the activities of a process. This level of integration if often applied when the local decision autonomy of process participants should not be controlled by a workflow system, i. e., if applications are provided as tools to the process participants, but the workflow system does not control the usage of these tools.

Function-level integration is typically implemented within technical processes (with little human participation) that are enacted within or between applications.[166] These processes serve the economic goals of the enterprise (e. g.,

161. For interoperability contracts in business-to-business processes refer to Goodchild, Herring and Milosevic (2000).
162. Standardized protocols for process interoperability, as they are discussed in section 3.4.5 on page 133, may incorporate ways to limit the visibility of process information. The value of information in the supply chain was discussed by Holten et al. (2002).
163. Compare Kugeler (2000), p. 18.
164. Within this taxonomy, integration is defined as the unification of disparate system elements to a new entity. For a detailed discussion of integration within the domain of workflow management refer to section 3.2.4 on page 111.
165. Note that recent efforts around the development of Web Services, and Service-Oriented Architectures (SOE) aim at the exposition of application functionality to external parties at a finer level of granularity using standardized interface descriptions.

the automated transfer of a delivery note to customer systems) and are designed at a higher level of abstraction than software processes, which are traditionally hard-coded within application systems.[167]

Granularity

The granularity dimension describes the representation of process objects that are passed from one activity to the next. Depending on the level of abstraction and the domain of a process, either atomic data elements (e. g., a customer number), or complex objects (such as scanned documents, manufacturing parts, or finished products) are moved along the process. The granularity dimension indicates the level of abstraction of the process, and the proximity of the process description to a technical implementation.

Validity

The validity dimension relates to the intention of the process representation. An *as-is process* reflects the current implementation of a particular process. If the process description represents a mid-term goal for either organizational or technical developments that still have to be implemented we call it a *target process*. The delta between the current process and the target process indicates potential for change within the organization and can serve as a guideline for restructuring efforts. An *ideal process* is a representation of the best possible process implementation, but it may be too costly or too complex to realize under the current circumstances. Whether there is a significant difference between a target process and an ideal process is determined by the current organizational configuration, available resources and other constraints, such as legal issues, or cost/benefit ratios.

Individuality

The individuality dimension of a process denotes whether the process is specific to a single organization (e. g., the specific brewing procedure for a patented drug), or whether it is a general representation, valid for a particular domain (e. g., an invoice verification process for car manufacturers). An

166. Within a single application system, an integration process may be executed to transfer data between disparate components of the application system. A typical example for this are systems based on a middleware infrastructure such as CORBA or a J2EE application server. Compare for example Weske (CORBA) (1997).

167. Note that an increasing number of workflow systems is used to construct process-oriented application systems. Vendors such as BEA, IBM, and Versata provide workflow components as parts of their software development infrastructure. Application vendors such as SAP, Siebel, and Oracle offer embedded workflow components that can be used to refine the software processes within their large-scale application systems. We can observe a trend to remove the top-level control flow from applications and have it managed by internal workflow components. This type of software architecture is labeled by some as Business Process Management System (BPMS), compare Smith, Fingar (2003).

enterprise-specific process is valid for a single organization, but is not necessarily internal to the organization. Inter-organizational processes, which are specific to a particular company, can also be classified as enterprise-specific processes.[168]

Reference processes are valid beyond the scope of a single enterprise, but they can be used for the design of individual processes.[169] While reference processes represent abstract types of enterprise-specific processes, they can be instantiated through the addition of enterprise-specific information and thus become enterprise-specific processes.[170]

Recipient

The recipient dimension describes the level to which a specific process contributes to the overall company output. This dimension is based on PORTER'S classification of primary and support activities.[171] Primary activities are those activities that contribute to the production of a company's output and its delivery to the consumer, as well as post-sale activities, such as maintenance of delivered products. In contrast, support activities are designed to support the primary activities and each other.[172]

In a similar notion, *core processes* create value and have a direct relation to the goods and services created by a company.[173] Core processes create value for the organization. *Support processes* ensure the enactment of the core processes through the provisioning of resources, material supplies, and the maintenance of the company's infrastructure. From a customer perspective, support processes do not create value, but without them a company's core processes would not be functional. The distinction between core and support processes depends on the specific configuration of a company. For example, a hiring process would be regarded as a support process within many companies, but for a recruitment company this processes would constitute a core process.

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168. Compare Kugeler (2000), p. 17.

169. An example for this use of reference processes is the Process Handbook project at the Massachusetts Institute of Technology, which collects process models from various industries and tries to inductively generate a repository of reference processes. Compare Malone et al. (1993) for a description of the project and Lee et. al. (1998) for a discussion of the modeling method applied to the reference models of the process handbook.

170. For a thorough discussion of reference models and reference processes compare Schütte (1999), pp. 69-86.

171. Compare Porter (1986), pp. 38-45.

172. PORTER names five categories of primary activities: inbound logistics, operations, outbound logistics, marketing and sales, and service. For support categories he names four categories: procurement, technology development, human resource management, and firm infrastructure. Compare Porter (1986), pp. 39-43.

173. Compare Becker, Kahn (2001), p. 7.

Abstraction

A *process instance* represents an actual occurrence of a particular process, such as the specific insurance claim of a customer. It describes the sequence of activities for a specific configuration of a process object and shows no abstraction or generalization.[174]

A *process type* is the general description of possible activity sequences for a certain type of process object (e. g., expense reimbursement form). It can serve as a template for individual process instances, which resolve the ambiguities of the process type.[175]

Hierarchy

The hierarchy dimension indicates whether a particular process is part of the operative or the management system of the enterprise. *Management processes* contain planning, decision, and control activities, while *operative processes* consist of activities that lead to the production of a company's goods and services, and the maintenance of the infrastructure necessary for the enactment of these activities. The *strategic management process* determines the overall goals and guidelines for the company, while the *operative management process* coordinates and controls the implementation of these strategies through the operative processes and in conformance with corporate goals.[176]

Now that we have established a definition for an organization's processes and their context, we look at the organizational structure surrounding a company's processes.

2.2.4 Development of Process-oriented Organizations

TAYLOR'S scientific management approach initiated the separation of management tasks for the operative core of the enterprise.[177] In combination with stable markets, predictable customer behavior, and long product life cycles, companies relied on functional specialization to increase the efficiency of task completion. As a consequence, the functional organization was the prevailing structure for the majority of 20th century organizations.[178]

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174. Compare Kugeler (2000), p. 18.
175. A process type can contain alternative sequences of activities, depending on certain attributes of the process object. A process instance derived from such a process type would contain only one of the alternative sequences, determined by the actual attribute values of the process object instance handled within this process instance.
176. For a detailed discussion refer to section 2.3.2 on page 57.
177. Compare Taylor (1947).

With changing market conditions, such as global competition and the creation of micro-markets, increasingly individual customer profiles that led to mass customization, and shorter product life cycles due to technological innovation, the dynamics of the corporate environment have changed dramatically. STALK, EVANS, and SHULMAN point out the transformation from externally oriented organizations toward a focus on internal capabilities:

> *"When the economy was relatively static, strategy could afford to be static. In a world characterized by durable products, stable customer needs, well defined national and regional markets, and clearly identified competitors, competition was a "war of position" in which companies occupied competitive space like squares on a chessboard, building and defending market share in clearly defined product or market segments. [...]*
>
> *[Today,] in this more dynamic business environment, strategy has to become correspondingly more dynamic. Competition is now a "war of movement" in which success depends on anticipation of market trends and quick response to changing customer needs. Successful competitors move quickly in and out of products, markets, and sometimes even entire businesses. [...] In such an environment, the essence of strategy is not the structure of a company's products and markets but the dynamics of its behavior."*[179]

The internal orientation of organizations has fueled the interest in methods and technologies to understand and manage the behavior of companies more efficiently, and with more effective results. As discussed in the previous section, an organization's output is generated by the organization's operative system through the execution of financial, logistics, and information processes. Using the system view of organizations[180], enterprises are facing the constant challenge to find the answer to the question: *How can we manage the operative system of the firm in such a way that the logistics, financial and information processes are performed efficiently and effectively?*

178. A functional organization structure groups the entities of the organization according to their functional specialization in order to maximize the resource efficiency. Compare Braun, Beckert (1992), col. 640-655. Advantages of the functional structure are economies of scale due to the size of the resulting departments, specialized (i. e., function-oriented) management and simplified recruiting and training according to Dessler (1986), pp. 125-127.

179. Compare Stalk, Evans, Shulman (1992), p. 62.

180. Compare section 2.1.2 on page 30.

In the context of process-oriented organizations, NORDSIECK noted the necessity of a process-oriented organizational structure:

> *"The true structure of an enterprise is a flow. With every cycle it continuously creates and distributes new products and services on the basis of the same or only slightly changing tasks. [...] Based on this perception, how can one order the tasks of an enterprise differently, but following the natural-technical segments of the flow?"*[181]

NORDSIECK even predicted the process-oriented design of information systems:

> *"Think about [a] modern data processing [system]. This, too, represents a significant process that is even connected with the business process and accompanies - or even controls - this process across different segments."*[182]

A process-oriented organization is structured in such a way that the organizational entities are grouped according to the processes they perform. The emphasis of process-oriented organizations is on the optimization of process-, market- and motivation-efficiency, while the maximization of resource and delegation efficiency are of lesser importance.[183]

Even though the origins of process-oriented organizations can be traced back more than 30 years, the interest in process-oriented organizations did not emerge until the late 1980s. As a result of this shift in interest, we have seen the process as the focal point of organizational structuring in the 1990s. Numerous process design, redesign, and management approaches were published at that time that proposed either an evolutionary or a revolutionary impact on existing organizational structures.[184] The common use of the term *process* in approaches such as Business Process Improvement (BPI)[185], Process Innovation (PI)[186], Business Reconfiguration (BRC)[187], Business Process Reengineering (BPR)[188] or Business Reengineering (BR)[189] can be

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181. Nordsieck (1972), col. 9.
182. Nordsieck (1972), col. 9.
183. Compare Kugeler (2000), pp. 77-78, who points out that a situative valuation of the individual efficiency goals is mandatory. Especially the compensation of process efficiency through a higher resource efficiency in the case of functional specialization has to be analyzed on a process-individual basis.
184. For a criticism of the various process (re-)engineering approaches compare Davenport (1995).
185. HARRINGTON defines Business Process Improvement as "a systematic methodology developed to help an organization make significant advances in the way its business processes operate [...] The main objective is to ensure that the organization has business processes that eliminate errors, minimize delays, maximize the use of assets, promote understanding, are easy to use, are customer friendly, are adaptable to customers' changing needs, provide the organization with a competitive advantage, and reduce excess head count." Harrington (1991), pp. 20-21.
186. Refer to Davenport (1993).
187. See Venkatraman (1992).
188. Compare Johannson et al. (1993); Stoddard, Jarvenpaa (1993) and (1994).
189. See Hammer, Champy (1993); Hammer (1996).

attributed to the refocusing of organizations on their processes. While BR and BPR aimed at the fundamental restructuring of an organization's processes[190], PI looked at the integration of information technology in this concept.[191] BPI relied on a less radical approach, focusing on the continuous improvement of business processes through the implementation of a quality framework in the tradition of the Total Quality Management idea.[192] The structural adjustment of organizations to provide a better fit for existing processes was addressed at a general level in all these publications, but an operational work plan for the design of process organizations did not emerge.[193]

2.2.5 The ARIS Framework for Process Analysis and Design

Organizational processes exhibit structural complexity both through the variety of activities and transitions found within an enterprise and through the variety of perspectives that can be applied to processes during their analysis. In its most simple form, a process consists of activities and the transitions between these activities. While any sequential algorithms can be implemented using just three control flow elements (sequence, iteration and selection)[194], organizational processes require constructs for the description of complex control flows, such as conditional and unconditional splits and joins.[195] In addition to the control flow, the support (or even the execution) of activities through application systems is interesting for information system designers. In addition, information about the data flow from and to individual activities is necessary for the design of process-oriented application systems. From the perspective of an organization designer, the responsibilities for activity execution need to be described (in other words: which resource is responsible for the execution of a specific activity). Process models can be employed for a variety of purposes, including software selection,

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190. Compare Hammer, Champy (1993), p. 32: "Reengineering [...] is 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."

191. While HAMMER and CHAMPY'S work named information technology as an "essential enabler" of reengineering (Hammer, Champy (1993), p. 44), it fails to outline specific steps to implement reengineering in practice ("For instance, we have written only a little about how organizations can actually make reengineering happen", Hammer, Champy (1993), p. 216). DAVENPORT tries to operationalize this approach and defines a stepwise procedure for the modeling and improvement of business processes.

192. Compare Harrington (1991).

193. Compare Hammer, Stanton (1999), p. 108, who point out the clash of redesigned processes with existing organization structures: "Many companies have integrated their core processes combining related activities and cutting out ones that don't add value, but only a few have fundamentally changed the way they manage their organizations. The power in most companies still resides in vertical units [...] and those fiefdoms still jealously guard their turf, their people, and their resources." A procedure model for the design of process-oriented organizations was proposed by Kugeler (2000).

194. Refer to Böhm, Jacopini (1966), pp. 367ff.

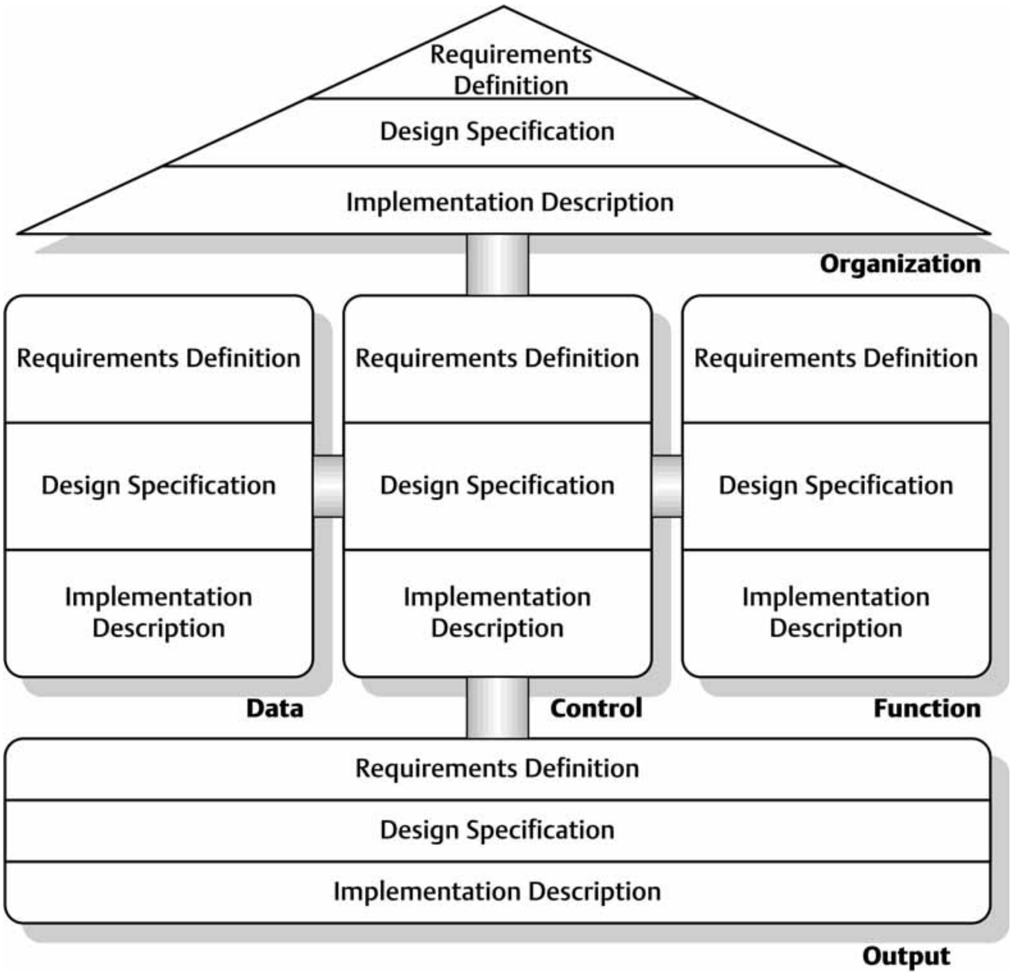
195. This is due to the fact that the concurrent execution of activities within an organizational process is easier to realize than the technical implementation of an algorithm with concurrent threads.

customization of software systems, software development, development of process-oriented applications, and process simulation. These perspectives are typically used by application designers. Benchmarking, activity-based costing, certification, knowledge management, and business reorganization are potential perspectives of the organization designer.[196] A framework for the analysis of processes is necessary to accommodate these different perspectives and requirements. Such frameworks reduce the complexity of process models through the introduction of different views. Examples for these frameworks are the ZACHMAN framework for application design, KRUCHTEN'S 4+1 view for object-oriented system architectures, and SCHEER'S Architecture of Integrated Information Systems (ARIS).[197] In the following section we use ARIS as an exemplary framework for process analysis.

ARIS was developed as a framework for the analysis and design of information systems, and distinguishes five different perspectives on a business scenario: Organization, data, function, output and control view. Each of these perspectives is divided into three layers, which are common across all perspectives. These layers relate to the system development process: Requirements definition, design specification, and implementation description.[198] Figure 2-7 shows the overall structure of the ARIS framework.

Although the primary purpose of the ARIS architecture was to serve as a framework for business-oriented software design and development, it has found widespread acceptance for organizational modeling and analysis purposes.[199] This can be attributed to the complexity reduction that is achieved through the different views. This complexity reduction enables an organization designer to focus on a specific part of the problem at hand, while irrelevant perspectives are filtered out. For example, while a database engineer is clearly interested in the data view, he will have less interest in the output view or the organization view.[200] Additionally, the phase concept of requirements definition, design specification, and implementation description allows modelers to specify parts of an organization using a method that

196. Compare Rosemann, Schwegmann (2001), p. 58.
197. Compare Scheer (1999) and Scheer (2000).
198. At the same time, these layers replace a fifth view, the resource perspective, which would include the information technology used within the process. Compare Scheer (1994), pp. 12-13.
199. Based on the ARIS architecture, a framework for the management of processes has been proposed by Scheer, the so-called ARIS house of business engineering, which covers different phases of the design of business-oriented application systems, from the conceptual modeling of business processes to the implementation of workflow applications. Compare Scheer (1996); Scheer (2000), p. 3.
200. In this example, the organizational view may be relevant to the database designer for the development of access control mechanisms, but not for the design of the logical database schema.



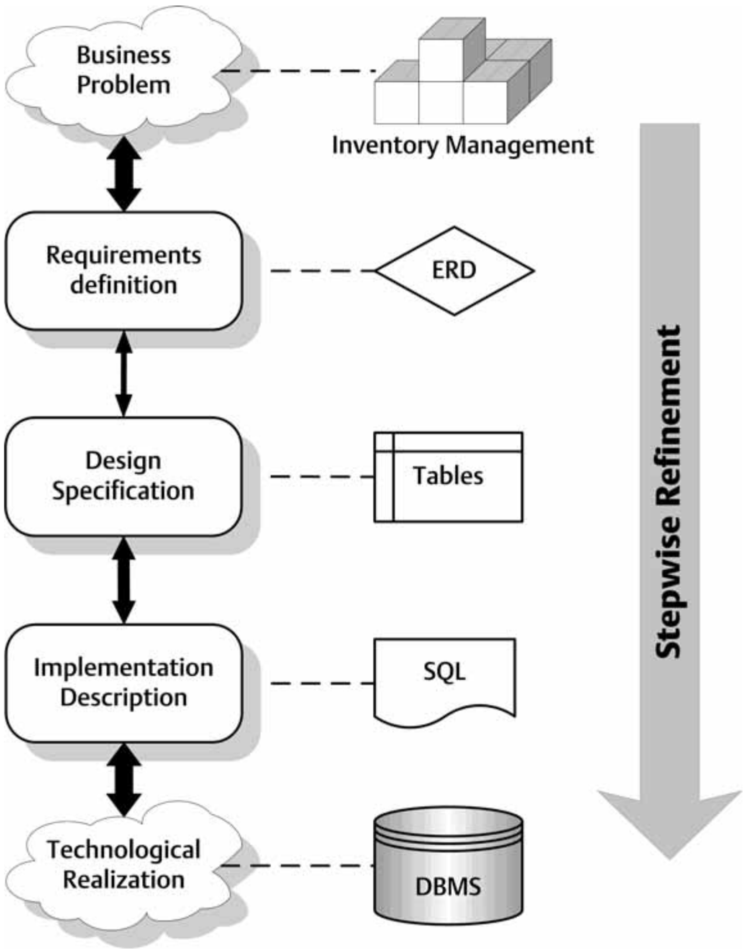
Source: Compare Scheer (1999), p. 41.

Figure 2-7: Architecture of Integrated Information Systems

matches the situation of the model recipient. Figure 2-8 illustrates the ARIS phase concept using the example of designing an inventory management database.

Starting with an operational business problem, a model of the requirements is specified using a conceptual modeling language, in this case an entity-relationship diagram. Based on this model the relational model of an inventory management database is designed using a structured description of the database tables. In the implementation description phase, this table structure is transformed into Structured Query Language (SQL) statements that are necessary to implement the proposed structure in a database management system (DBMS). The actual implementation concludes the project and, as a result, a solution for the business problem is available.

The ARIS framework is a *normative* collection of views on processes, i. e., the selection of views is based on experiences from process modeling projects and has been influenced by the event-driven process chain (EPC) as



Source: Compare Scheer (1998), p. 39.

Figure 2-8: ARIS Phase Model

a particular modeling language for processes.[201] In the following section we discuss the individual views of the ARIS framework in more detail.

Function View

The *function view* of the ARIS framework contains process activities and allows the modeler to create a hierarchical decomposition of high-level activities into activities of finer granularity. Through the function view activities from different processes can be grouped according to different attributes, e. g., all activities with customer interaction. SCHEER explicitly allows the use of application software symbols and corporate goals in the function view, which can be used to illustrate the purpose of activities, and

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201. The event-driven process chain was first introduced by Keller, Nüttgens, Scheer (1992). It is regarded as a semi-formal process modeling language, because no explicit meta-model was the basis for its inception. The lack of a rigid methodical foundation has been criticized by some authors, who prefer the rigor of modeling methods based on mathematical formalisms, such as Petri-Nets (Petri (1962)). Compare e. g. v. Uthmann (1997); v. Uthmann (1998) and v. Uthmann (2001). A (language-oriented) meta model for the EPC was first provided by Rosemann (1996), pp. 122-123.

to represent automated activities which are implemented through software applications, respectively.[202]

Organization View

The *organization view* contains resources that participate in the execution of a process and/or have responsibility for the process, in whole or in part. This includes not only the performers of activities, but also their managers, customers, suppliers, and so forth. Although the organization view is mostly used to depict the hierarchical structure of an organization, it can also be used to model interactions between resources.[203]

Data View

The *data view* of the ARIS framework hosts the messages and events that trigger processes and activities, as well as environmental data that is transformed through the execution of activities (i. e., a customer record that is updated through the activity “change delivery address”).[204]

Output View

Within the *output view*, the input and output of activities and processes are defined. SCHEER defines output as “the result of a production process, in the most general sense of the word.”[205] The defining criteria for output is the fact that it is required as input by some party other than the producer, that it has been requested by the receiving party, and that it is of value.[206] Output recipients of an activity or process can reside inside or outside the organization, i. e., output can be produced for both internal and external customers. The output view was introduced in the last revision of the ARIS framework, while in earlier editions the elements of the output view were represented in the data view of the framework.[207]

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202. Compare Scheer (1999), p. 36.
203. Resource interactions can be used to represent business processes. One example for this type of process model is the action workflow approach, compare Winograd, Flores (1985) and Medina-Mora, et al. (1992) and Mentzas, Halaris, Kavadias (2001). Another example (to a certain extent) is the collaboration diagram of the Unified Modeling Language (UML), which depicts interactions between objects (which can be representations of resources). Compare Hruby (1998); Eriksson, Penker (2000), pp. 47-48; Object Management Group (2001).
204. Refer to Scheer (1999), pp. 35-36.
205. Refer to Scheer (1999), p. 13.
206. Compare Scheer (1999), p. 13.
207. Compare for example Scheer (1994), p. 13.

Control View

The *control view* (sometimes called process view) represents the union of the other four views and describes the dynamic behavior of a process, whereas the organization, data, function, and output views describe the structural properties of a process.[208] The control view contains the complete process model, comprised of activities and control flow, their in- and output, resources involved in their execution, triggers and messages. It connects the entities described in the other views through named relationships, such as “controls”, “creates”, “triggers”, or “uses”.

Evaluation

The ARIS framework provides modelers with a selection of distinct views for the modularization and analysis of organizations. It has found widespread acceptance in practice[209], partially due to available modeling software support.[210] The partial models of the data, organization, function, and output view can be integrated through the control view, enabling the distributed modeling of partial aspects of an organization by different parties and the subsequent integration into a unified model. Especially in larger organizations the availability of a central modeling repository and the option of distributing modeling tasks among a group of analysts is a precondition for the use of modeling software.

In the previous sections we have outlined what business processes are, their relationship to the structure of organizations, and ways to describe and analyze these processes. In the following section we analyze the impact of emerging process organizations on the role of management.

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208. Compare Scheer (1999), p. 36.
209. For case studies from ARIS projects compare for example Scheer, Jost (2002).
210. The ARIS Toolset of IDS Scheer AG provides software support for modelers using the ARIS framework.

2.3 Management of Process Organizations

2.3.1 Management - Concepts and Definitions

The origin of modern management theory can be seen as the publication of FAYOL'S general principles of management in 1916, which provided a first classification of managerial tasks.[211] Within management theory the role of management can be approached from an institutional as well as from a functional perspective. While the former deals with the description of the organizational entities that perform managerial tasks, the latter addresses the processes and activities that are performed by these entities.[212]

Institutional Interpretation of Management

The institutional interpretation of management focuses on the positioning of managerial entities within the organizational structure. Within this interpretation we can identify a significant difference between German and American management approaches. Within the German organizational literature, management is perceived as the highest organizational layer of the enterprise. In contrast, American authors discuss management as any position that has disciplinary or direct authority over another position in the organization.[213] Critics of the latter position often point out that the personified understanding of management mixes manager-employees with manager-owners. This integration poses a problem for industry-economical research that aims at comparing enterprises managed by owners with enterprises managed by independent employees.[214]

Functional Interpretation of Management

The functional interpretation of management focuses on the activities that are performed with the intention to control the operative process of the enterprise. Typically these activities are performed by specific parts of the organization (thus linking the functional interpretation to the institutional interpretation of management). Most authors describe management as a cross-sectional function that controls the use of resources and choreographs the operative activities of the enterprise. STEINMANN and SCHREYÖGG define management as a conglomerate of controlling activities, which have to be performed during the production of goods and services, and ensure their success within division-of-labor-systems.[215] Typical management func-

211. See Fayol (1949). While TAYLOR'S work on scientific management was concerned with the separation of the organizational decision system from the executing system elements, FAYOL'S work aimed at the classification of managerial tasks.
212. Compare Staehle (1999), p. 71.
213. Refer to Steinmann, Schreyögg (2000), p. 6.
214. Compare Schreyögg, Steinmann (1981).

tions include planning, organization, and control of the enterprise, although a large number of different functional classifications exist.[216]

One of the most influential categorizations of management functions was given by GULICK[217], who built upon the work provided by FAYOL.[218] His classification consists of seven distinct functions:

- *Planning*: The general decision what has to be done and how it should be done in order to achieve corporate goals.
- *Organizing*: The creation of a formal structure of authority that forms and defines work units, and coordinates these work units in relation to the overall goal.
- *Staffing*: The recruiting and training of personnel and the constant achievement of adequate working conditions.
- *Directing*: The continuous decision-making in individual cases, and the subsequent development of individual or general guidelines.
- *Coordinating*: The general task to connect various parts of the work process.
- *Reporting*: The continuous information of the superior organizational level about the development of the work process. This includes continuous self-information and the provisioning of information to subordinate employees.
- *Budgeting*: The execution of all tasks that comprise budgeting, especially the creation of a budget and its supervision.

This functional catalog was subsequently modified by different authors. For example, BLEICHER classifies management functions in three categories:[219]

- *Design* of an institutional framework that enables an operating unit's capacity to survive and adapt.

215. Compare Steinmann, Schreyögg (2000), p. 7.
216. See, e. g., Steinmann, Schreyögg (2000), p. 6-7. This rather simplistic view of management functions has been criticized, e. g., by MINTZBERG in his seminal paper "The Manager's Job: Folklore and Fact". In this paper, he states: "If you ask a manager what he does, he will most likely tell you that he plans, organizes, coordinates and controls. Then watch what he does. Don't be surprised if you can't relate what you see to these four words." Mintzberg (1975), p. 49. He adds: "The field of management, so devoted to progress and change, has for more than half a century not seriously addressed the basic question, 'What do managers do?' Our ignorance of the nature of managerial work shows up […] in the computer consoles gathering dust in the back rooms because the managers never use the fancy on-line MIS some analyst thought they needed."
217. Compare Gulick (1937), p. 13, cited after Steinmann, Schreyögg (2000), p.8.
218. See Fayol (1949), which was first published in 1916.
219. Compare Bleicher (2001), p. 54.

- *Direction* through the specification of goals and the definition, initiation, and evaluation of goal-oriented activities within the system and its elements.
- *Development* is, on the one hand, the result of design and direction processes over time. On the other hand, development happens independently in social systems through the evolutionary learning of knowledge, achievements, and attitudes.

2.3.2 Management Control as a Feedback Loop

KOONTZ and O'DONNELL were the first to substitute the functions coordinating, reporting, and budgeting with a single function: *controlling*.[220] Modern management theory thus relies on the five functions: planning, organizing, staffing, directing and controlling. These functions are arranged in a temporal and logical sequence along the management process.

The *planning phase* addresses the selection of corporate goals and the selection of the best way to achieve these goals.[221] On the highest level, planning deals with the development of goals, strategies, programs, and procedures for either the entire organization or certain parts of the organization. The management process starts with the planning phase, which serves as a primary function, i. e., it creates the original input for all subsequent phases of the management cycle.

The *organizing phase* deals with the development of an execution framework for the plans and processes that were described in the previous planning phase. Primary goal of the organizing phase is the development of an organizational structure that consists of positions and their aggregations (groups, departments, etc.). Furthermore, the distribution of competencies and qualification requirements for these positions, and the development of a communication system along the organizational structure are tasks within the organizing phase.[222]

The *staffing phase* is concerned with the population of the organizational structure that was designed in the organizing phase. Following the initial staffing phase, the staffing function has to ensure and continuously maintain the supply of qualified resources for the organization.

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220. Compare Koontz, O'Donnell (1955), cited after Steinmann, Schreyögg (2000), p. 8-9.
221. Compare Steinmann, Schreyögg (2000), p. 9.
222. Note that the term *communication system* in this context does not relate to technical communication equipment such as telephones, fax machines, and computer networks. Instead, the rules and regulations for communication between the members of the organization have to be determined during this phase (for example, which position reports to whom).

While planning, organizing, and staffing are primarily concerned with the preparation of the organization for efficient operation, the *directing phase* contains the continuous initiation of task enactment and the coordination and control of the operative system.

The final phase of the management cycle is the *controlling* or *evaluation phase*, during which the achievements of the operative system are compared with the plans devised during the planning phase. Planning and controlling phases are regarded as twin functions, since controlling is impossible without the target measures provided by the planning phase, while planning is hardly possible without controlling information about the achievement (or attainability) of goals.

Figure 2-9 shows the management process according to BLEICHER.[223] The cyclic process emphasizes that management must not only be perceived as a linear sequence of activities, but that it is rather an interconnected feedback loop, consisting of the three core phases decision, enactment and evaluation.[224]

The management process as described above is not an isolated sequence of activities executed on the management level. Instead, each part of an organization performs - to some extent - steps within the management cycle. Due to the sheer complexity of large organizations a central coordinating instance cannot be implemented with reasonable effort. One of the main reasons for this is the limited information processing capacity of the human brain.[225] In order to ensure an optimal decision making process (which includes the optimal allocation of resources) information about the entire organization has to be aggregated and evaluated. Another reason for the lack of centralized control are structural defects of decision processes.[226] There-

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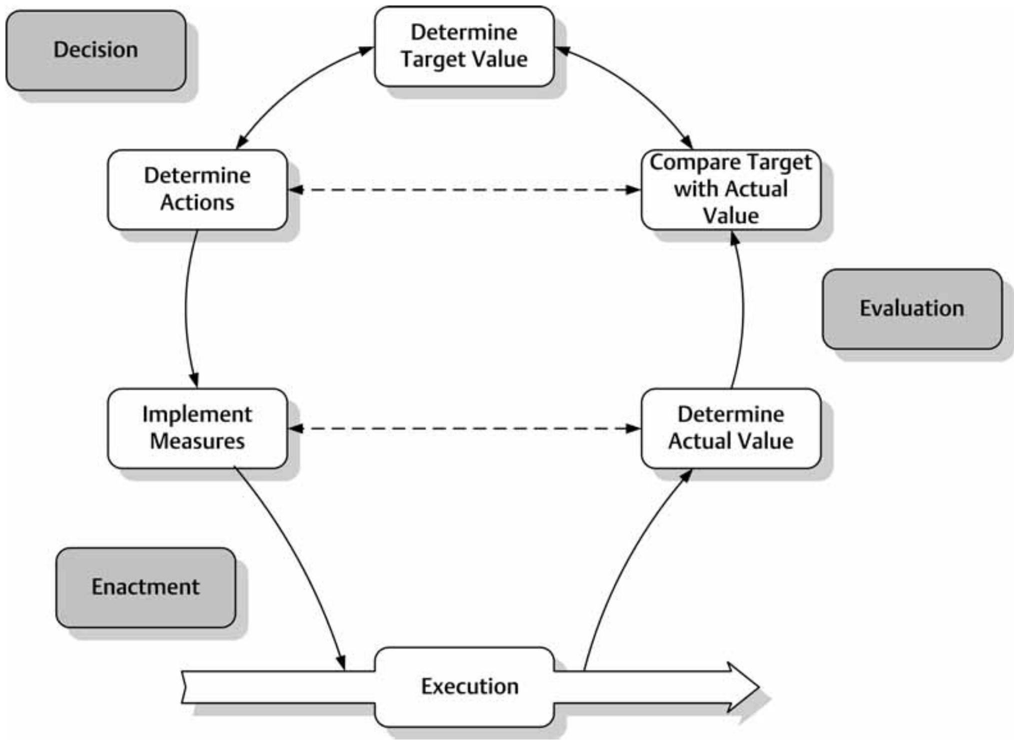
223. Refer to Bleicher (1999)[48], p. 49. The management process depicted here is a modified version of the management process proposed by ULRICH and KRIEG, compare Ulrich, Krieg (1974).

224. This cycle shows structural similarities to the Deming cycle depicted in figure 1-1 on page 3.

225. Compare Dessler (1986), pp. 110-113, who describes the increasing information load: “As managers are faced with more and more information - with more uncertain information, more complex information, or more types of information - they reach their capacity for processing it and making decisions, and information overload occurs.”

226. ADAM has classified the problems associated with complex decision making processes. *Solution defects* can be found if for a certain problem more than one solution is possible (e. g. the planning of production lots). *Goal defects* occur if certain desirable outcomes of an activity are in direct conflict (e. g., maximizing the return on investment while minimizing the risk of loss). *Valuation defects* can be observed when the outcome of a certain decision cannot be measured precisely (e. g., additional revenue from the development of a new product). Finally, *impact defects* occur when the results of proposed activities cannot be determined with certainty. This category of defects occurs frequently, when the internal workings of organizational processes are not understood, and the relationship between input factors (e. g., materials and human resources) and output factors (e. g., defect-free products) are unknown. For a detailed discussion see Adam (1996), pp. 10-15.



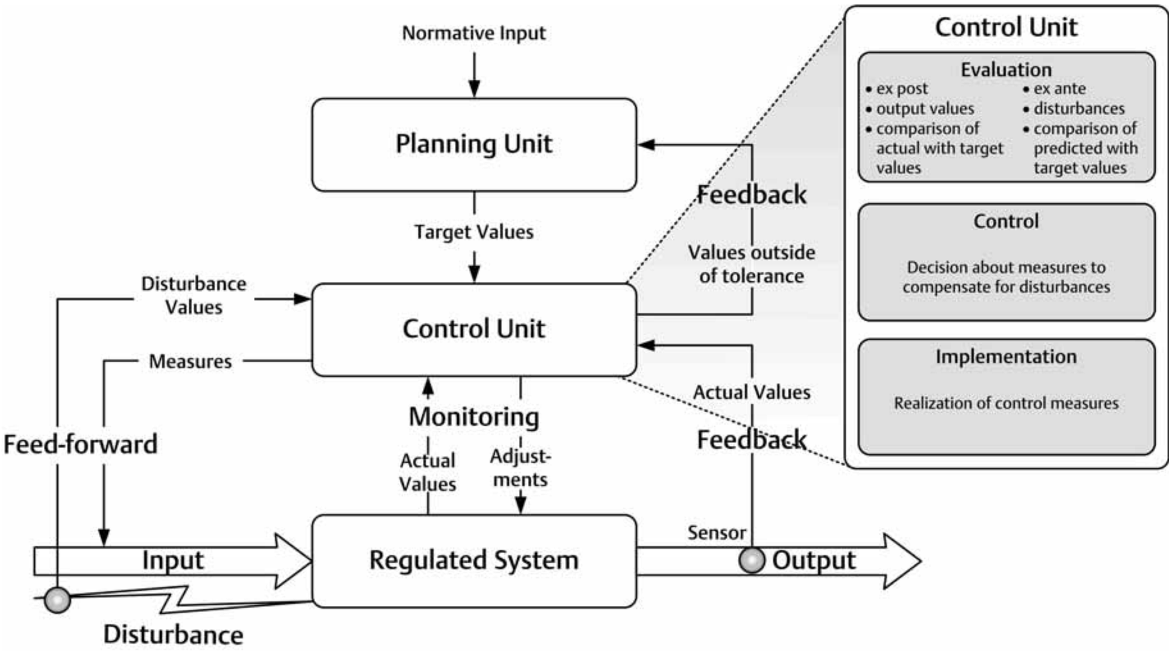
Source: Compare Ulrich, Krieg (1974); Bleicher (2001), p. 49.

Figure 2-9: Cyclic Management Model

fore, management processes are implemented at various levels of the organization, which enable the organization to continuously control itself, in order to maintain its viability and development.

The cyclic structure of the management process corresponds with the principles of the cybernetic feedback loop.[227] A diagram of the cybernetic feedback loop is depicted in figure 2-10. The operative system of the organization is the system being regulated by the control unit. The planning unit provides target values for the output of the regulated system to the control unit. Input for the planning unit comes from the normative management level, which determines overall strategies, rules, and guidelines for the organization. The control system has to ensure that the regulated system produces an output within the tolerances defined for the target values. This unit consists of three sub-units: Evaluation, control, and implementation. The evaluation part measures the output of the regulated system as well as its input (and eventual disturbances, which may affect the regulated system) through sensors. During traditional feedback coordination, the output values (actual values) are compared with target values provided by the planning unit. If a deviation exists within certain tolerance levels, the control part of the control unit determines the necessary measures to compensate for the

227. For the following section refer to Küpper (2001), pp. 181-185; Wiese (2000), pp. 18-20; Espejo et al. (1996), pp. 65-69.



Source: Compare Espejo et al. (1996), p. 67; Wiese (2000), p. 19.

Figure 2-10: Cybernetic Feedback Loop

disturbances that may have caused the deviation. The implementation part of the control unit performs the necessary adjustments to the input stream of the regulated system. This ex-post evaluation can compensate for disturbances within a certain bandwidth, but it does not prevent the system from attaining a state of self-oscillation.[228] In order to stabilize this lower feedback loop, the control unit reports deviation outside of the tolerance bandwidth to the planning unit, which can then adjust the target values appropriately. Anticipatory control (feed-forward control) is performed if the evaluation part of the control unit measures the disturbances before they enter the regulated system, and the control system can devise preventive measures to ensure the desired output. Finally, if a regulated systems allows a view of its internal processes, it can be monitored during the processing phase.[229] If the system also allows a modification of its processes, real-time adjustments can be administered through the control unit.

2.3.3 Levels and Tasks of Management

In section 2.3.1 on page 55 we have discussed the individual tasks that make up the management function of an organization. These tasks can be classified into different groups. The classification of managerial tasks can be traced back to the works of ANTHONY, who differentiates between three

228. Self-oscillation occurs when the planned compensation of a disturbance creates another disturbance in the opposite direction, which in turn is compensated by an adjustment in the direction of the original disturbance, and so forth.

229. Monitoring can be defined as the gathering of data on the performance of an existing system. Compare Lucas (1971), p. 80.

distinct categories of management tasks: Strategic planning, management control and operational control.[230] This distinction is based on the different objectives, focus, and information requirements of each category.

- *Strategic planning* is directed at the development, the maintenance, and the exploitation of success potentials, for which the organization's resources have to be used. It focuses on the organization in its entirety and relies on internal and external information at a coarse level. The relationship of the organization with its environment is a central issue within this category.[231]
- *Management control* is directed at ensuring the realization of strategic plans through the provisioning of appropriate resources and processes. It focuses on the human and technical resources of the organization and relies on guidelines that are provided by the strategic planning entities, as well as on reported information from the underlying operative system.[232]
- *Operational control* is directed at the efficient and effective enactment of the operative activities. GORRY and SCOTT-MORTON point out that operational control mainly deals with tasks, whereas management control mainly deals with resources.[233]

An overview of the different categories of management activities is given in table 2-1.[234]

Based on this classification, a typical segmentation of management levels is the distinction between strategic, tactical and operative management. This distinction is based on a number of criteria:[235]

- The *position* of the manager in the organizational hierarchy and the potential for delegating decisions to subordinate units.

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230. Compare Anthony (1967), Gorry, Scott-Morton (1971), p. 59. Some authors call the strategic planning level normative management, which deals with the overall goals of the enterprise, with principles, norms and rules that are designed to foster the ability of the organization to survive and to develop. Compare Bleicher (2001), p. 74.

231. Compare Gorry, Scott-Morton (1971), p. 58.

232. Anthony defines management control as "the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives". Anthony (1967), p. 27.

233. Compare Gorry, Scott-Morton (1971), p. 57.

234. Compare Anthony (1967).

235. Compare Hentze, Brose (1985), pp.117-118.; Welge, Al-Laham (2001), p. 6. Both authors distinguish between three levels of managerial activity: strategic, operative and tactical level. They refer to operative planning as the middle level and tactical planning as the lower level of managerial activity. In order to reflect the distinction between the management and operative systems discussed on page 34, we use these terms in the reverse order, as they are found in Wiese (2000), pp. 45-50.

	Objective	Focus	Information Requirements	Information Characteristic	Information Sources
Strategic Planning	Deciding on objectives and policies for the organization	Organization	Information about the organization and the environment	Infrequent, aggregate and obtained from outside the organization	Balanced Scorecard On-line Analytical Processing
Management Control	Acquisition, efficient and effective use of the organization's resources	Resources	Limited information about the environment, information about the organization	Guidelines and regulations from strategic planning, actual values from operational control	Activity-based Costing On-line Analytical Processing
Operational Control	Efficient and effective enactment of tasks	Processes and Resources	Information about the organization	Frequent, accurate, precise from inside the organization	Operational learning and control system

Table 2-1: Categories of Management Activities

- The *scope* of the managerial decisions, i. e., which parts of the organization are affected by a decision made at this specific level.
- The *object* of managerial activities, i. e., the frequency, novelty, and validity of decisions, the possibility of revising a decision, the flexibility in making specific decisions, and the formalization of decisions.
- The *structure* of managerial decisions, i. e., criteria such as the complexity, security, level of detail, degree of freedom, and information requirements.
- The *process* of managerial decisions, i. e., the programmability of the decision process, the thought-style, behavior, and interdependencies.
- The *stimulus* for managerial decisions, i. e., whether decisions are made in an anticipatory way (feed forward), or if they are triggered by organizational events (feedback).

Table 2-2 shows a juxtaposition of the characteristics of strategic and operative management.[236] The attributes denote extremes of a continuum and should be interpreted as "more common in strategic management" versus "more common in operative management". In the following section we discuss strategic and operative management and control in more detail, and outline the different information requirements of both groups.

Strategic Management and Control

		Strategic Management and Control	Operative Management and Control
Decision Object	**Scope**	entire organization	departments, single units
	Validity	general	(case-)specific
	Reversibility	low, expensive	high, inexpensive
	Flexibility	very high	very low
	Frequency	low	high
	Novelty	innovative	repetitive
	Formalization	weak	strong
	Authority	centralized	decentralized
Decision Structure	**Complexity**	high	low
	Certainty	high risk	low risk
	Structure	unstructured (open)	structured (closed)
	Level of Detail	low, global	high, specific
	Degree of Freedom	high	low
	Inform. Requirements	high	medium/low
Decision Process	**Programmable**	not possible	partially possible
	Normative Input	high	low
	Thought Style	holistic, intuitive, synoptic	analytical, incremental
	Behavior	innovative, creative	routine, repetitive
	Interdependencies	few	frequent
	Stimulus	feed-forward control	feedback control

Table 2-2: Juxtaposition of Management Levels

The purpose of strategic management and control is the alignment of the entire organization based on external conditions (e. g., the market situation) and internal capabilities. Corporate strategy addresses the selection of strategic business units, the choice of competitive behavior[237], and the identification of core competencies. Strategic management and control is directed at

236. Compare Hentze, Brose (1985), pp. 117-118. Note that HENTZE and BROSE use the term tactical planning for what is named operative management in table 2-2. The middle level has been eliminated from the table, because the attributes shown are a continuum and a medium level would necessarily have a fuzzy distinction. Also, some of the attributes chosen by HENTZE and BROSE have been omitted, because they no longer reflect the current state of management science. For example, STEINMANN and SCHREYÖGG have pointed out that the temporal scope of decisions no longer is a distinctive feature of strategic or operative management, respectively. Strategic plans can have a short-term scope, such as the acquisition of a competitor due to a surprise offer or a turn-around effort in times of economic peril. Also, the position of strategic management tasks at the top of the organizational hierarchy, while valid in many cases, is not a fixed rule. For example, reengineering efforts that are initiated by members of the operative system may have a strategic impact on the organization as a whole (e. g. the introduction of a document management system in place of existing paper flows). Compare Steinmann, Schreyögg (2000), pp. 149-150.

237. For example, whether the organization strives to attain cost leadership or quality leadership.

the creation, maintenance, and exploitation of success factors. For these purposes resources are employed.[238] This generic strategy specifies the fundamental approach taken by an organization to pursue competitive advantage and provides a framework for operative activities.[239] STEINMANN and SCHREYÖGG identify the following elements of strategic management and control:[240]

- *Strategic analysis.* Besides strategic control, strategic analysis is the core task of strategic management, because it provides the information framework for the successful selection and implementation of a strategy. This task is comprised of the analysis of the environment, and the analysis of the organization. Goal of the environmental analysis is the identification of threats and opportunities for the organization's activities from the perspective of markets, competitors, and customers (immediate environment). To a lesser extent, the analysis of general trends in society, political structures, and technological factors (distant environment) is part of the environmental analysis.[241] Goal of the organizational analysis is the identification of strength and weaknesses in terms of resource potential and capabilities, product portfolio, and financial assets, which could provide a competitive advantage. The results of environmental and organizational analysis are often combined in form of a SWOT-analysis (strengths, weaknesses, opportunities, threats).[242]

- *Evaluation and selection of strategic options.* Based on the findings of the strategic analysis, alternative strategies are designed and evaluated. Based on the valuation of different strategies, one of the alternatives is chosen for implementation. Besides the factors identified during the strategic analysis, ethical and management philosophical factors are considered during this phase.

- *Development of a strategic program.* Strategic programs provide orientation for the operative planning and control processes. They provide guidelines and procedures for the implementation of corporate strategies, but do not outline the implementation processes in detail. The

238. Compare Bleicher (2001), pp. 75-76. BLEICHER identifies a normative level of management, which deals with the overall goals of the organization and develops principles, norms and guidelines that enable the company to sustain and develop. Compare Bleicher (2001), pp. 74-75. This management level relates to the culture, politics and constitution of the organization and is therefore outside the scope of our research. For the remainder of this work the analysis is restricted to the two lower levels: strategic and operative management and control.

239. Refer to Porter (1985), p. 25.

240. Refer to Steinmann, Schreyögg (2000), pp. 157-160.

241. Compare Steinmann, Schreyögg (2000), p. 158.

242. For a description of the SWOT analysis refer to Meffert (2000), pp. 67-68.

emphasis of strategic programs is the provisioning of operative goals for parts of the organization, which enable the different units to assess the current implementation using measures and variables that relate to these goals. The actual implementation of strategic programs is not a task of strategic management.

- *Strategic control*. The continuous evaluation of the activities of the operative system encompasses the strategic management process. While some authors see strategic control as the final phase of the strategic management cycle, several arguments can be given for an encompassing view of strategic control.[243] On the one hand, a feedback-based control cycle does not deliver information in time, which could lead to corrective measures during the implementation of the strategic plan.[244] This is due to the long planning cycles and potential irreversibility of strategic decisions made. On the other hand, changes in the factors analyzed may require a revision of planning assumptions, but these changes are only communicated upstream during a new cycle of the management process or the control phase. Therefore, strategic control has to accompany the management process and has to continuously question its assumptions and results.[245] During the different phases of the management process two types of strategic control can be distinguished:[246] *Premise control* continuously monitors the assumptions made during the development of strategic programs. *Execution control* continuously monitors the implementation of the strategic program.

Information Requirements

Information requirements describe the type (quality) and amount (quantity) of information required to satisfy the information needs of a decision maker. Information needs have to be satisfied in such a way that the uncertainty about the consequences of choosing a particular alternative are minimized. Members of an organization involved in strategic management and control have different information requirements during the different stages of the planning and control process. During the strategic analysis, information sources both internal and external to the organization are required. For instance, the analysis of the environment is based on market data, demographic information, and competitor information, among others. Information about the performance of different organizational units is required for

243. Compare Schreyögg, Steinmann (1987).
244. Compare Steinmann, Schreyögg (2000), p. 243.
245. Refer to Band, Scanlon (1995).
246. Compare Preble (1992). Some authors combine execution control and premise control with strategic monitoring. Compare Steinmann, Schreyögg (2000), pp. 245-247.

the analysis of the organization. This information may be put in perspective through related external information, such as benchmarks[247] for particular processes or products.[248] In the context of strategic control, internal information about the achievement of milestones during the implementation of strategic programs, as well as the contribution of different organizational units to the overall goals of the organization is required. Premise control requires information about the current state of planning assumptions.

Methods and Instruments

The execution of successful control as part of the strategic management process depends on the precise definition of benchmarks, milestones, and other metrics. Such metrics should reflect the intention and progress of the strategic program, and should relate to the overall strategic goals of the organization. Traditionally, this is achieved by the use of financial measures, which have the goal of making otherwise incomparable facts comparable through a common valuation. These financial measures are typically extracted from the operative accounting systems of the company and aggregated using ratio systems, such as the RoI system of E. I. du Pont de Nemours.[249]

Besides financial measures, which outline the cost aspect of a company's activities, non-financial measures are used to evaluate criteria such as quality, timeliness, and service levels. KAPLAN and COOPER emphasize the use of non-financial measures:

> *"Cost reduction is an important managerial objective. But cost improvement alone may not be sufficient. Customers want not only lower prices and costs; they also greatly value quality, responsiveness, and timeliness. Consequently, employees must have information about both the cost consequences of their activities and the quality and cycle time of processes under their control."*[250]

The performance measurement movement focuses on the use of non-financial measures as an equal source for the selection of strategy alternatives, staffing considerations, and other decisions. It aims to extend their traditional role as additional information for the enhancement of existing financial frameworks.[251]

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247. Compare Eccles (1991), p. 133: "Benchmarking involves identifying competitors and/or companies in other industries that exemplify best practice in some activity, function, or process and then comparing one's own performance to theirs."

248. Compare Lamla (1995) and Schmitz (1998) for a comprehensive discussion of process benchmarking.

249. Refer to Staehle (1973), pp. 224 ff.

250. Kaplan, Cooper (1998), p. 49.

Table 2-3 shows the evolution of cost accounting systems according to KAPLAN and COOPER.[252] Many companies today rely on information from stage II systems, which provide cost information from responsibility centers, but not related to activities, processes, services or customers.[253] The system output is backward-oriented and made available with a significant delay, due to the fact that feedback-style controlling is employed. The integration of non-financial measures and cross-departmental information sources is seen as the biggest improvement potential for existing cost reporting systems.[254]

	Stage I Systems Broken	Stage II Systems Financial Reporting Driven	Stage III Systems Specialized	Stage IV Systems Integrated
Data Quality	■ Many errors ■ Large variances	■ No surprises ■ Meets audit standards	■ Shard databases ■ Stand-alone systems ■ Informal links	■ Fully linked databases and systems
External Financial Reporting	■ Inadequate	■ Tailored to financial reporting needs	■ Shard databases ■ Stand-alone systems ■ Informal links	■ Fully linked databases and systems
Product/ Consumer Costs	■ Inadequate	■ Inaccurate ■ Hidden cost and profits	■ Several stand-alone activity-based costing systems	■ Integrated activity-based management systems
Operative and Strategic Control	■ Inadequate	■ Limited feedback ■ Delayed feedback	■ Several stand-alone performance measurement systems	■ Operative and strategic performance measurement systems

Table 2-3: Evolution of Cost Accounting Systems

Operative Management and Control

Purpose

Operative management and control operates within the framework provided by activities on the strategic level. Its purpose is the execution and enactment of strategic plans with the organization's specific resource contingencies. For this purpose the strategic programs have to be broken down into partial plans, structured by functional areas, product divisions, or regions. ODIORNE has proposed the following procedure model for the transformation of a strategic goal into operative goals:[255]

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251. The term performance measurement was coined by Eccles (1991). Criticism of existing accounting systems, which are the main source for financial information about an organization, was stated by Kaplan (1983) for the manufacturing domain and Johnson, Kaplan (1987) on a more general basis.

252. Refer to Kaplan, Cooper (1998), p. 12.

253. See Kaplan, Cooper (1998), pp. 13-18.

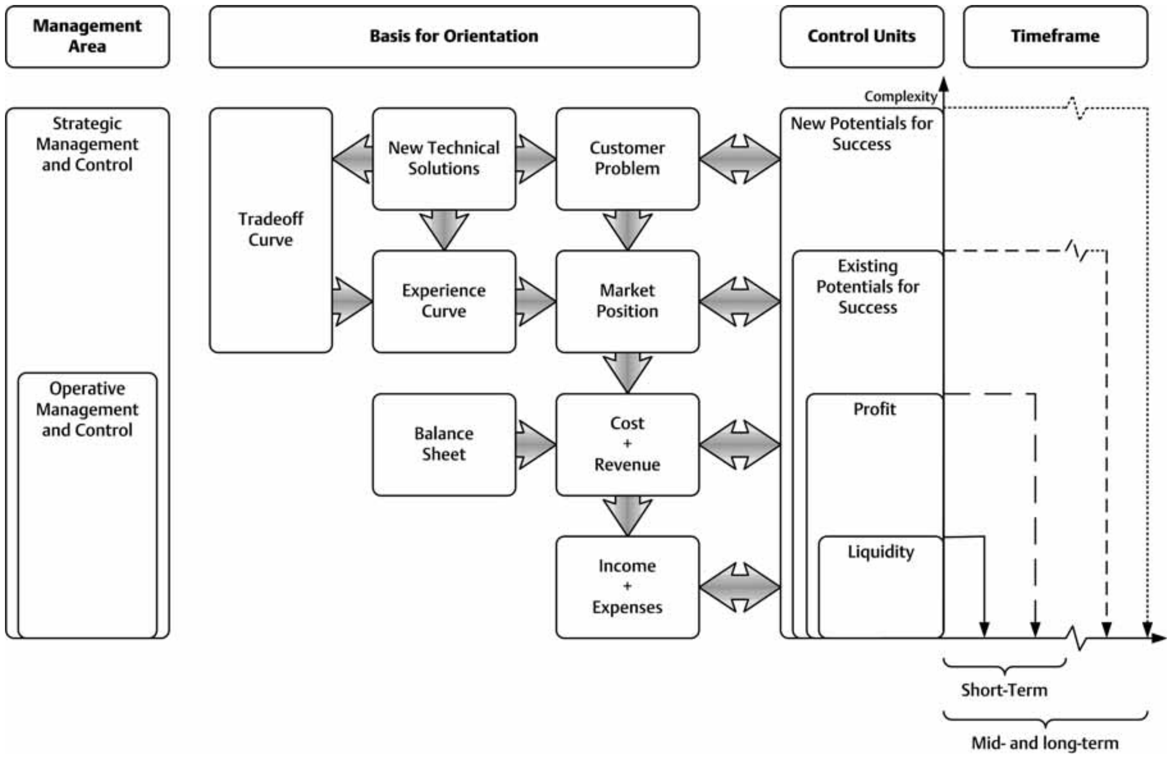
254. Refer to Ittner, Larcker (1999), who even argue that non-financial measures are better indicators for the financial performance of a company than financial measures themselves.

- Identification of a *responsible person* for a particular time frame and a particular result.
- Identification of *indicators* that reflect the achievement of the goal.
- Selection of *key indicators* from the pool of indicators identified in the previous step.
- Decision about additional *constraints* which have to be recognized.
- *Operationalization* of key indicators and constraints through the agreement on temporal and quantitative target values.
- *Implementation* of the agreed-upon program.

The transformation of strategic programs into operative activities is seen as the central weakness of strategy implementation.[256] In contrast to the procedural approach presented by ODIORNE, an integrated system of indicators for managerial activities has been proposed by GÄLWEILER.[257] The basis of this framework is the liquidity of the company, since it presents a condition for the survival of the organization. Due to its short-term orientation, a plan based on liquidity goals (taking income and expenses into account) would neglect the future-orientation of the company. For this reason, the analysis of a company's profit through cost and revenue provides the means to control the liquidity over a longer period of time. However, the planning of balance sheets for the development of long-term strategies neglects experience curves and the substitution potential of a company's products through its competitors. Therefore, existing core competencies and success potentials form the basis for the next level of strategic planning. While these indicators allow for a longer planning period, they do not recognize changing market conditions, technological innovation, and changing customer profiles. The continuous search for new success potential thus forms the highest level of corporate strategy. Figure 2-11 shows the management model by GÄLWEILER.

The planning and control cycle at the operative level focuses on the implementation of the strategic programs developed during the strategic planning and control cycle. Operative planning consists of the development of implementation plans for logistics and financial processes as well as the development of project plans for their actual implementation.[258] Operative

255. Compare Odiorne (1979), p. 121, whose management system is called *management by objectives.*
256. Refer to Staehle (1999), p. 663.
257. Compare Gälweiler (1987), p. 34.
258. Compare Steinmann, Schreyögg (2000), pp. 266-274.



Source: Gälweiler (1987), p. 34.

Figure 2-11: Management Tasks and Indicators

control measures the progress of implementation and focuses on the efficiency of the plan realization (“doing the things right”), whereas strategic control focuses on the validation of goals (“doing the right things”).[259] Besides the development of operative work plans and measurements, operative control executes a reporting function in the direction of strategic control. Because of the different intentions of operative and strategic control, the scope of this reporting task can grow to a size that impacts the efficiency of the original tasks of operative control.

Information Requirements

The information requirements of operative management and control are twofold. On the one hand, measurements are required that allow operative management to monitor the implementation of (parts of) the strategic program within their control sphere. On the other hand, information has to be gathered which is subsequently passed on to the strategic control level. For this reason, a reporting infrastructure needs to be implemented that not only satisfies the information requirements of the operative management, but also allows the integration and aggregation of its results across organizational boundaries. A process controlling system needs to satisfy these requirements.

259. See Steinmann, Schreyögg (2000), p. 368.

2.4 Controlling of Process Organizations

2.4.1 Controlling of the Firm - Concepts and Definitions

The organizational position of the controller has been a result of corporate practice,[260] but it is lacking a theoretical foundation which outlines potential development paths for controllership in practice.[261] This problem arises from the variety of definitions of the term controlling, of which none is universally accepted.[262] The interpretations of the term controlling range from the positivistic view *"Controlling is what controllers do"*[263] to information-centric, coordination-centric, or management-centric definitions.[264] We discuss each of these views in the following section, before we discuss their integration in hybrid controlling definitions.

Information-Centric Controlling Definitions

The information-centric view on controlling focuses on the position of the controller as a central information supplier.[265] The controller has to support the decision making process through the supply of timely and relevant information. For this purpose, an infrastructure for the collection, management, and presentation of this information has to be created and maintained. This aspect represents the system-building function of the controller. Through the use of such a controlling infrastructure, the controller gathers information from sources inside and outside the organization, aggregates them to levels that reflect the information requirements of the decision problem at hand, and ensures that decision makers have access to relevant information. This aspect represents the system-utilizing function of the controller. The core responsibility of the controller is the coordination of information generation and supply with the existing information demand.[266] Through this activity, the controller assumes responsibility for the transparency requirements of management.[267] WEBER points out that through this supporting task the controller disburdens management.[268] Since the infor-

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260. The first roots of controllership in private companies can be traced back to the position of the comptroller at the Atchinson, Topeka & Sante Fe Railway System in 1880. For a detailed discussion of the historic roots of controlling see Weber (1999), pp. 2-10.

261. See Schäffer, Weber, Prenzler (2001), p. 2.

262. A critical discussion of the lack of agreement on the definition of controlling is part of many controlling books. For a reference compare e. g. Schildbach (1992), pp. 21-27 and Weber (1999), pp. 19-29, who points out the lack of *generally accepted controlling principles.*

263. A critical perspective on this view can be found in Grob (1996), pp. 1-2.

264. Compare for a discussion Weber, Schäffer (1999), pp.732-734. ANTHONY has characterized the different views of controllership as follows: "In practice, people with the title of controller have functions that are, at one extreme, little more than bookkeeping and, at the other extreme, de facto general management." Anthony (1965), p. 28.

265. Compare e. g. Becker (1984).

266. Compare Küpper (2001), pp. 10-11.

267. Compare Weber (1999), p. 348.

mation requirements of decision makers vary with the actual decision to be made, the information supply function of controlling is highly context-dependent.[269]

The information-centric view of the controller is closely related to the domain of management accounting in the English literature. This view includes the functions of operations research, budgeting, tax accounting, and corporate revision as activities of the controller. While the information supply function was historically dominated by the use of financial measures and related key indicators, this focus has been questioned since the mid-1980s and alternative measurements for aspects such as product quality, customer satisfaction, and process efficiency have been proposed.[270] However, the simple equation controlling = advanced management accounting ignores the additional functions of the controller, which we discuss in the following section. Table 2-4 shows the juxtaposition of the main attributes of management accounting and controlling according to BECKER.[271] While the descriptions given in table 2-4 are extremes, which are unlikely to be found in corporate practice, they outline the differences between the two functions.

Besides the provision of information, the controller is also responsible for supplying the appropriate methods for the analysis of the information at hand. These methods reach from frameworks for financial measures[272] to scorecards that provide a holistic view of the enterprise and its subsystems.[273]

Management-Centric Controlling View

The management-centric controlling view defines controlling as a specific function of the management system. The controller has to ensure the efficiency of the management cycle by continuously monitoring the alignment of managerial activities with the enterprise goals.[274]

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268. Compare Schäffer, Weber, Prenzler (2001), p. 4.
269. Compare Weber (1999), p. 39; Kaplan (1984), p. 414 points out the context dependency of management accounting approaches: “Management accounting must serve the strategic objectives of the firm. It cannot exist as a separate discipline, developing its own set of procedures and measurement systems and applying these universally to all firms without regard to the underlying values, goals and strategies of particular firms.”
270. Compare Kaplan (1984), p. 414, who argues that management accountants should expand their perspective beyond the use of financial measures: “The option to include non financial measures in the firm’s planning and control system will be more unfamiliar, more uncertain, and, consequently, less comfortable for managerial accountants. It will require them to understand those factors that are most critical to the company’s long-term success.”
271. Refer to Becker (1984), p. 22, cited after Weber (1999), p. 22.
272. Compare for example the DuPont-System of Financial Control, which was established 1919. Compare Horváth (2001), pp. 571-574.
273. Compare for example Kaplan, Norton (1996) and Kaplan, Norton (2001).
274. Refer to Weber (1999), pp. 23-25.

Management Accounting	Controlling
Number-oriented activities	Recipient-oriented activities
Goal: Numbers have to be recorded and adjusted properly	Goal: Numbers have to lead to activities
Accountant	Information supplier and salesperson
Work is backward looking	Work is forward looking
Numbers are delivered	Numbers are sold (recipients need to be convinced)
Work in secrecy	Continuous communication about revenue questions
Rigid guidelines	Continuous adjustment to corporate require-ments
Domain-specific terminology	Translation in recipient-oriented terminology
Reports based on numbers	Reports with look-ahead, summary, résumé, information and (proposed) measures
Dominates accounting	Dominates goals, plans and control

Table 2-4: Juxtaposition of Management Accounting and Controlling

Coordination-Centric Controlling View

Until recently, the majority of controlling definitions emphasized the task of coordinating the different elements of the management system.[275] Coordination can be defined as the process of achieving unity among interdependent entities.[276] Within the management cycle, the task of the controller can be seen as the coordinating entity, which ensures the effective collaboration of different parts of the management system, such as planning, control, organization, personnel management of goal definition.[277] The controller has to ensure the efficiency and effectiveness of the management system in the same way the management system has to ensure the efficiency and effectiveness of the operative system.[278]

275. Compare for example Küpper (2001), pp. 12-29; Horváth (2000), pp. 118-120.

276. Compare e. g. Dessler (1986), p. 148, who defines coordination in relation to tasks: “Coordination is the process of achieving unity of action among interdependent activities.” MALONE and CROWSTON define coordination in its most general form as “managing dependencies between activities.” Malone, Crowston (1994), p. 90.

277. Compare Weber (1992), pp. 172-179. Note that Weber subsequently modified his position and now advocates the rationality-supporting function of controlling, which is presented in section 2.4.2 on page 73.

278. See Weber (1999), p. 26.

Hybrid Controlling Definitions

While the information-centric, management-centric, and coordination-centric view of controlling describe different perspectives that can be applied to classify the activities of a controller, most controlling definitions combine elements from all three perspectives. For example, HORVÁTH'S definition of controlling has found widespread use in the German literature:

> *"Controlling is - from a functional perspective - the sub-system of management, which coordinates planning, evaluation,[279] and information supply in a goal-oriented, system-building, or system-connecting way. By doing so, controlling supports the adaptation and coordination of the entire system."[280]*

The above definition sees controlling as goal-oriented, i. e., it supports the overall economic goals of the enterprise. It has to coordinate conflicting strategies, which may lead to local optimization, and it has to ensure an overall economic benefit for the organization. It is seen as a specific part of the management system, which it coordinates. The management system itself consists of the two sub-systems planning and control system and information-supply system.

2.4.2 Controlling as a Measure to Ensure Rational Management

The above controlling definitions have been criticized in the literature for a variety of reasons:

From a system perspective, if controlling coordinates the management system, it cannot perform a management function in itself. Coordination of a system can only be performed from a system of higher order, thus controlling would be a meta-management function.[281] Most controlling definitions, however, claim that controlling is a sub-system of the management system. Industrial practice shows that management and operative functions are closely interwoven, and that the separation of management and operative system is not applicable in all cases.[282] Also, the normative definition of management sub-systems, chosen by the authors favoring the coordination view, is lacking an explanation for why the particular structure of the management system is the best possible segmentation, or if the structure is exhaustive. The separation of management sub-systems suggests a high

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279. Note that Horváth uses the German term *Kontrolle*, which translates to *controlling*. In order to avoid a homonym conflict and a misleading recursive definition, the term *evaluation* has been chosen for the translation.

280. Horváth (2000), p. 153.

281. Meta (Greek: above) denotes the location of the controlling system above the management system which it coordinates.

282. Compare Weber (1999), p. 28. See also footnote 124 on page 34.

degree of structure within the management system, but fails to accommodate situative management decisions.[283]

WEBER argues that a common framework for controlling tasks is necessary, although the tasks of information supply, coordination, and managing systems reflect the controlling function only in part. He points out that the most general description of controlling is “to perform quality control for managerial tasks.”[284] The importance of a quality control function is based on the high level of complexity managers are faced with today. BLEICHER even argues that the core task of management is the management of complexity.[285] Complexity relates to the feature of systems that in a given period of time can take on a large number of different states, effectively making the understanding and management of the system difficult for humans.[286]

Complexity can be managed through the systematic division of work in combination with personal-professional specialization. This ultimately leads to depersonalized and technocratic systems[287] and structures, which are necessary to manage large-scale decentralized organizations.[288] These structures contradict the development of faster decision processes, shorter information cycles, and automated information flows. ULRICH and PROBST warn:

> *“If a company is caught in a web of detailed rules and regulations it loses its ability to spontaneously adapt to changing environmental conditions. It loses the flexibility necessary to survive in a volatile and changing environment.”*
>
> *“Complexity-reducing measures are correct if well-known goals are rationally and securely achieved using well-known pathways. They are wrong if new goals and pathways are explored. What we don’t know we can’t sensibly control!”*[289]

In the context of increasing complexity, the role of controlling can be defined as follows:[290]

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283. See Weber (1999), p. 29, who points out that “the following question is not answered: Can the system structure be maintained if new management problems demand new solutions?”

284. Refer to Weber (1999), pp. 38-39.

285. Compare Bleicher (2001), p. 31.

286. For a discussion of complexity refer to footnote 95 on page 26.

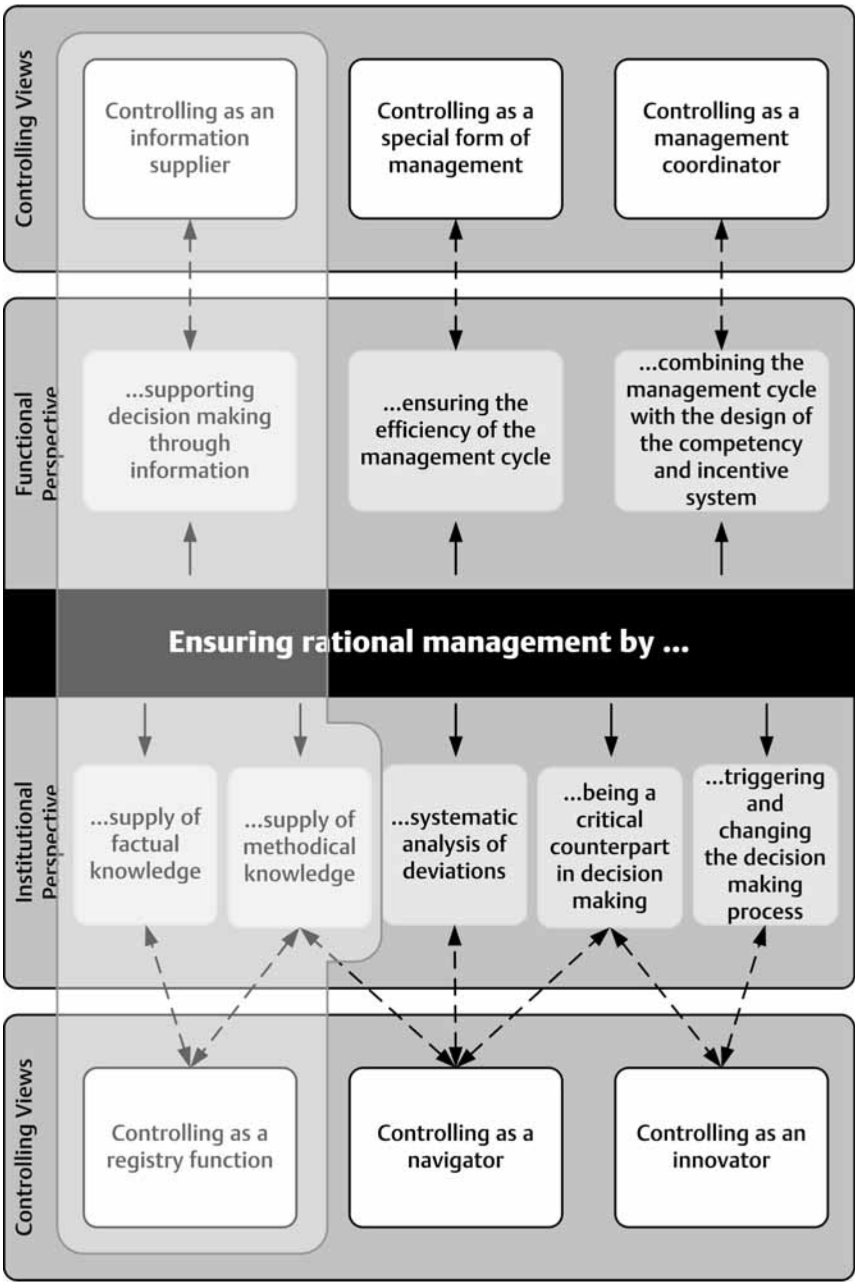
287. BLEICHER defines technocratic structures as the opposite of human-oriented structures. They are defined by formal mass-production programs, a task-oriented division of work which leads to horizontal interfaces (that increase the complexity) and vertical interfaces due to multi-level hierarchies. Instrumental and quantifiable factors are used to create an equilibrium among the distributed units. The result are short-term cost orientation and risk avoiding strategies. See Bleicher (2001), p. 593.

288. Compare Bleicher (2001), p. 32.

289. Refer to Ulrich, Probst (1988), p. 63.

290. Compare Weber (1999), p. 39; Weber, Schäffer (1999). For a critique of this position refer to Irrek (2002). Since IRREK’S definition of controlling as a control system ignores the information and method supply functions of controlling, WEBER’S approach is more suitable for this work.

Controlling has the goal to ensure the rationality of management through the provisioning of context-specific information and appropriate evaluation methods, and by continuously monitoring the planning and implementation process. Figure 2-12 provides a summary of the different controlling functions from an institutional and a functional perspective.



Source: Weber (1999), p. 40.

Figure 2-12: Controlling as a Function to Ensure Rational Management

The shaded area on the left side indicates the aspects of controlling relevant to this book, which focuses on the analysis of information supplied by workflow management systems and the methods that can be applied for the evaluation of this information.

2.5 Process Management and Process Controlling

2.5.1 Process Management

Process management can be perceived as the application of the management cycle with a focus on organizational processes. GAITANIDES ET AL. define process management as the collection of planning, organizing, and controlling activities for the goal-oriented management of the organization's value chain regarding the factors quality, time, cost, and customer satisfaction.[291] The main goals of process management are the achievement of transparency with regard to process structure and process contribution.[292]

NEUMANN ET AL. see the main task of process management in accompanying the process implementation, and ensuring the continuous, incremental improvement of the organization's processes.[293] Process management and process-oriented reorganization projects are not mutually exclusive. Instead, the restructuring of an organization with a focus on the processes should be followed by an institutionalized process management.[294]

VOLCK separates management into structural management, which deals with the structural properties of the organization, such as positions and departments, and process management, which focuses on the design of the organization's processes.[295] This strict separation does not hold in practice, because the institutional interpretation of process management requires the creation of process owners and process managers, which is clearly a task of structural management. In addition, the design of processes has a direct impact on the resources involved in the process and therefore influences the conditions under which structural management has to operate.[296]

GADATSCH defines process management as a component of an integrated concept for business process- and workflow management.[297] It consists of the tasks process definition, process modeling, and operative process management.[298] Relating to the ARIS phase model, GADATSCH places process management within the requirements definition phase, whereas workflow management constitutes the implementation phase. This approach has several weaknesses. On the one hand, the definition of process management is

291. See Gaitanides, Scholz, Vrohlings (1994), p. 3.
292. Compare Gaitanides, Scholz, Vrohlings (1994), p. 16.
293. See Neumann, Probst, Wernsmann (2002), p. 297.
294. Compare Neumann, Probst, Wernsmann (2002), p. 298.
295. Compare Volck (1997), pp. 24-27.
296. Compare Kugeler (2001), p. 61.
297. Refer to Gadatsch (2000), p. 369; Gehring, Gadatsch (1999a); Gehring, Gadatsch (1999b), p. 70.
298. GADATSCH uses the term "*Prozessführung*", which means operative leadership of processes. Refer to Gadatsch (2000), pp. 370-371.

recursive (if process management contains operative process management, what is the management part of process management?). On the other hand, not all processes of an organization are supported by workflow management. As SCHULTE-ZURHAUSEN points out: Only repetitive processes can be structured and thus organized and managed.[299] Creative or innovative processes, which are part of the management system, are not repetitive and thus cannot be managed formally (much less automated through workflow technology).[300]

If we take the management cycle as described in section 2.3.3 on page 60 and treat processes as the managed entity, the planning, implementation, and control phases can be integrated in the following procedural description of process management:[301]

- The management cycle starts with the *analysis phase*, which consists of the environmental analysis and the organizational analysis. As part of the *environmental analysis*, the market partners for the processes in question are determined (customers, suppliers, third parties) and their technical and organizational restrictions regarding the processes are identified (e. g., if an electronic interface to the systems of a partner is generally feasible). In addition, legal and competitive restrictions have to be analyzed (e. g., legal issues that arise from the flow of customer data across international borders). The environmental analysis can also deliver information on best practices found throughout the competition and through benchmarks from other domains.
  The *organizational analysis* deals with the assessment of the company's capabilities to implement and execute the processes in an efficient manner. Existing technical and organizational restrictions (such as the existing technological infrastructure) as well as the overall "fit" of the processes have to be determined (i. e., do the processes adequately reflect the policies and guidelines currently in place?).
- Based on the results of the analysis phase, an *evaluation and selection of design options* is the next phase. During this phase, alternative strategies about the outsourcing of processes or process parts as well as the technical infrastructure are identified and evaluated (for instance, a standard-software-based implementation versus an individual-soft-

299. Compare Schulte-Zurhausen (1999), p. 59; Kosiol (1976), p. 31.
300. A number of research projects about workflow support for unstructured processes exist (compare e. g. Blumenthal, Nutt (1995); Carlsen (1997); Glance, Pagani, Pareschi (1996); Nutt (1996) and Weske (Flexible) (1997)), but in most cases the implementation cost outweigh the benefits from an automated process coordination by far.
301. For a detailed description of a procedure model for a process-modeling project refer to Becker, Berning, Kahn (2002), pp. 20-23.

ware-based approach). Additionally, an enterprise-wide process framework is developed, which serves as an integration platform for the different processes and which can be used for orientation and communication purposes by the process designers and participants.[302]

- The next phase, *development of a project plan* outlines the implementation of the processes through the design of appropriate project plans. During this phase, reference processes or similar tools for the communication of the overall process strategy are developed.
- During the *implementation phase*, processes are deployed in the operative part of the organization, adjustments of the infrastructure resources supporting the processes are made, and staff training on new rules and regulations takes place.
- Following the implementation, the *continuous operative management* of processes has to ensure the efficient execution of the implemented processes through appropriate institutional structures such as process managers or process owners. Besides identifying responsible personnel, this phase focuses on the creation and usage of adequate infrastructures for information supply.

2.5.2 Process Controlling

Process controlling has been approached from two different perspectives in the controlling literature. While some authors focus on the advancement of traditional controlling toward a process-oriented controlling[303], other authors put the emphasis on the controlled object, i. e., enterprise processes.[304] For example, BREDE defines process controlling as an evolution from cost accounting and revenue management:

> *"The goal [of process controlling] is the creation of analytical transparency in the organization, which serves as a basis for the creative implementation of new processes, designed according to customer and market requirements."*[305]

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302. Compare, e. g., Meise (2000).
303. Compare Brede (1996), Brede (1997); Gerboth (2000).
304. Compare Scheer, Breitling (2000); Schmelzer, Friedrich (1997); Schmelzer, Sesselmann (2001).
305. Brede (1997), p. 155.

GERBOTH defines process-oriented controlling as a precondition for the controlling of processes:

> *"A first step is the creation of process-oriented controlling, which requires the alignment of controlling processes and instruments with the business processes. As a next step, the controlling of processes has to be implemented - a process controlling."*[306]

SCHMELZER and FRIEDRICH provide a functional definition of process controlling:

> *"The task of process controlling is the planning and monitoring of business process effectiveness and efficiency. It provides process managers with the information required for the control of their business processes. Process controlling has a significant impact on the success of products and R&D projects and thus on the productivity and competitiveness of a company."*[307]

Similar to the distinction of strategic and operative management, process controlling has a twofold purpose. At the strategic level, process controlling has to ensure that all organizational processes cooperatively support the organization's goals. For this purpose, process controlling has to provide an evaluation framework that allows the assessment of different processes using a common set of measures.

At the operative level, process controlling has to ensure the efficient execution of individual processes and the proper utilization of the resources required for process execution. Operative process controlling overlaps with operative process management, since both have the same purpose: The maintenance of operative process efficiency. However, while operative process management is embodied in process managers and process owners, process controlling serves the information supply function for process managers as depicted in figure 2-12. In the context of *process monitoring*,[308] status information about running process instances are presented to the participating (and qualified) members of the organization.[309] *Operative process controlling* provides aggregate information about completed process instances for further analysis.[310] An effective controlling system cannot rely on data from internal processes exclusively.[311] Rather, the entire supply chain should be the scope of the analysis, starting with relevant interfaces to market partners and ending with the delivery of finished products or services to the customers. This concept creates new recipients for controlling information outside

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306. Compare Gerboth (2000), p. 535.
307. Schmelzer, Friedrich (1997), p. 336.
308. Compare, e. g., Meyer (1997).
309. Compare Scheer, Breitling (2000), p. 399.
310. Compare zur Muehlen, Rosemann (2000).
311. Compare Scheer, Breitling (2000), p. 399.

the boundaries of the company. Suppliers and customers may request information about the progress of "their" process instances, and independent controlling bodies may be established for the management of supply chains.[312]

Figure 2-13 shows the functional decomposition of process controlling functions. Process controlling consists of three general support functions that are performed during the planning, implementation, and operational phases of process management. In addition, the information supply function of process controlling is a continuous task, and consists of the maintenance of a current process documentation and the provision of process reports.[313]

During the *planning phase*, process controlling supports the planning of alternative process structures through the provisioning of measurements of existing process designs, and simulation values of alternative process structures (e. g., processes with concurrent activities, eliminated process steps, etc.). In the course of this activity, process controlling supplies information about the goal contribution of process structures. In addition to the process structure, process controlling can also provide information to assist in process staffing decisions. Through an analysis of the existing skill-set of process participants and a requirements analysis of process activities an necessary training activities can be determined.

The planning of measurements and target values is necessary to integrate process goals into the information supply infrastructure of process controlling. The achievement of process goals cannot be determined without measurements. For this reason, two critical tasks of process controlling are the identification of suitable measurements that reflect the process goals, and the selection of target values for these measurements. Figure 2-14 shows the decomposition of the process structure planning activity, which is performed as part of the process management cycle, and the subsequent planning of process measurements and target values as part of the process controlling cycle.

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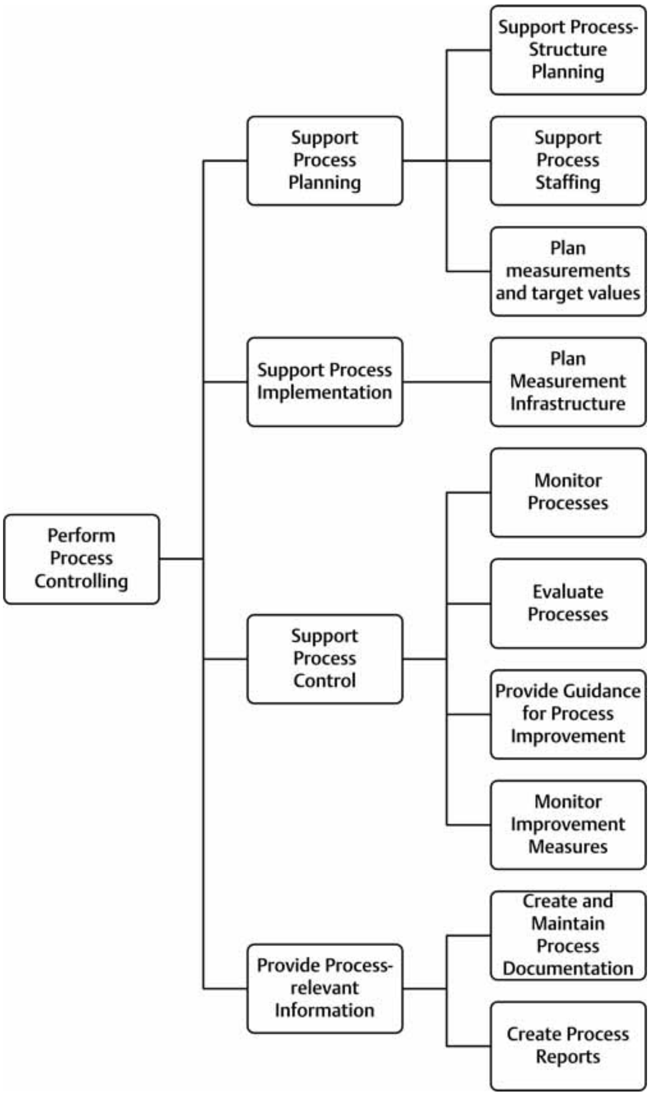
312. Compare Holten et al. (2002).

313. It can be argued that creating a process documentation is part of the planning, design, and implementation phase, and not necessarily a core function of process controlling, since process models (as a form of process documentation) can serve many different purposes, compare Rosemann, Schwegmann (2002), p. 52-58. For example, for communication and training purposes, process models may be used by the human resources department. These models are not the subject of process controlling efforts. However, an up-to-date documentation of processes is a precondition for the provision of process reports and thus is part of the process controlling function catalog. For this reason, the creation and maintenance of a controlling-oriented process documentation is seen as a task of process controlling.



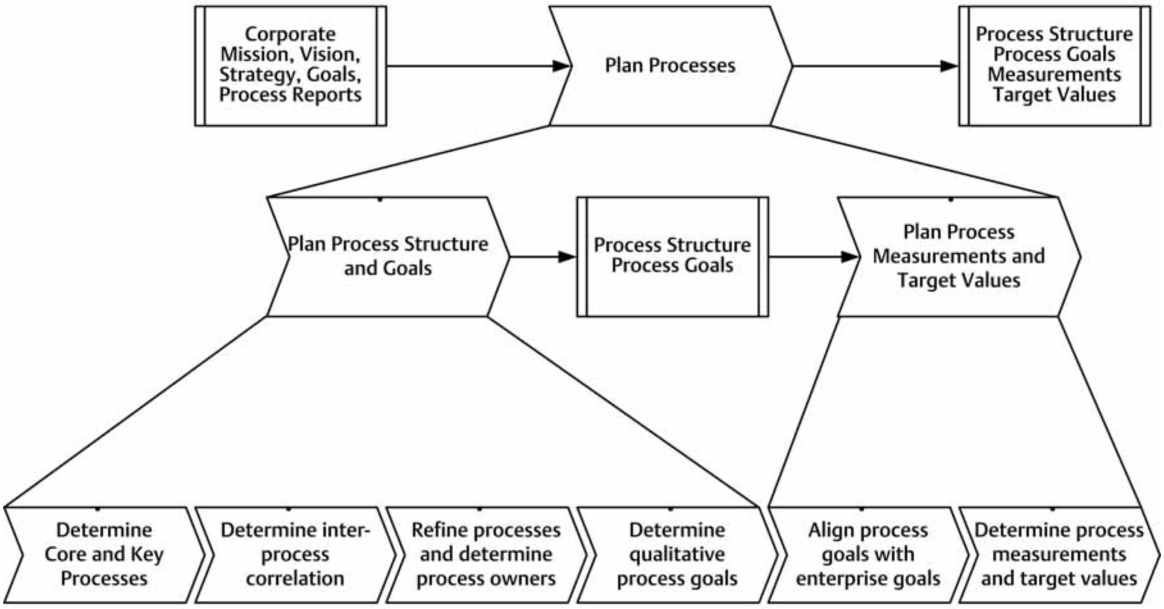
Source: Modified from Gerboth (2002), p. 44.

Figure 2-13: Functional Decomposition of Process Controlling

Process support in the *implementation phase* relates to the design of an infrastructure for process measurement. While the collection and integration of financial performance indicators is a well known task in traditional management accounting, process performance indicators also contain time-based information, such as turnaround times or idle times during process execution. In order to capture these values, a measurement infrastructure along the processes has to be established, e. g., by implementing reporting and messaging functions in process-oriented application systems.

During the *enactment phase*, process controlling supports operative process control through the continuous monitoring of running processes and the evaluation of completed processes. Possible directions for process improvement are indicated by process controlling. However, the selection and implementation of these measures is a task of process management.[314] Once

[314]. Compare Gerboth (2002), pp. 50-51.



Source: Compare Gerboth (2002), p. 45.; Kugeler (2000), pp. 189-190.

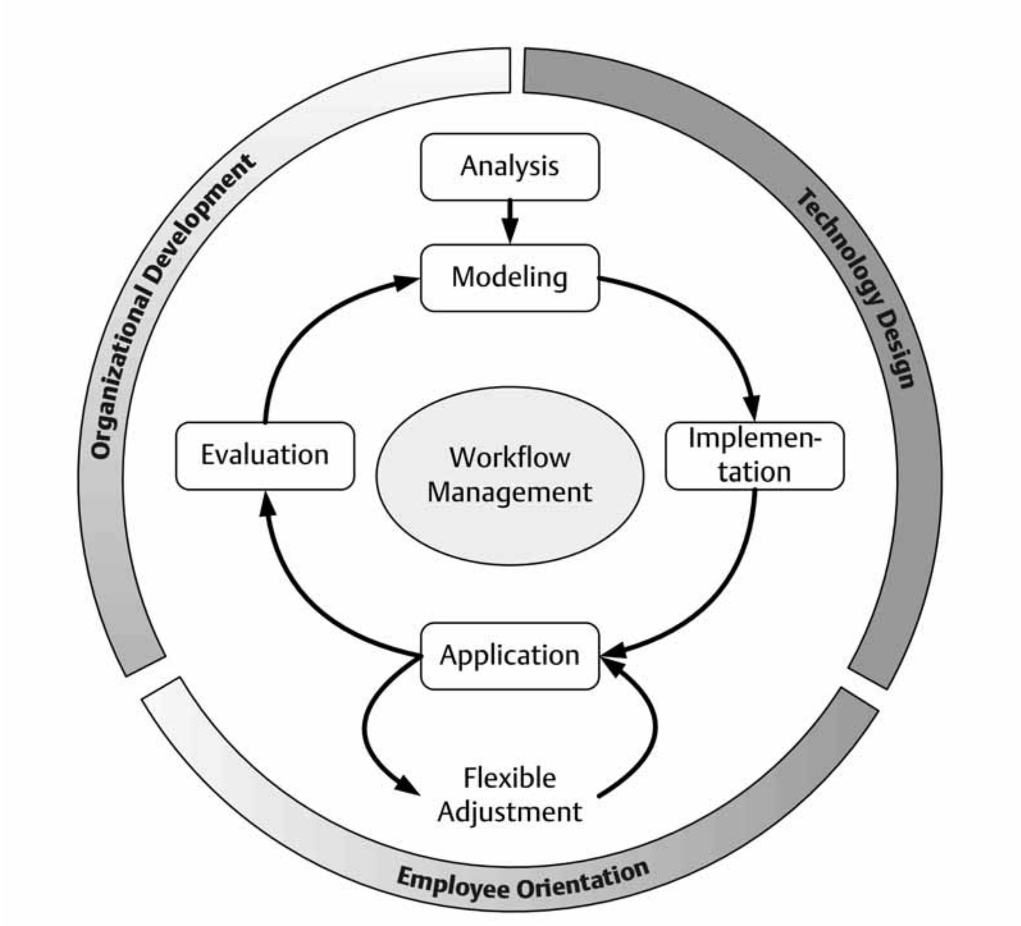
Figure 2-14: Decomposition of the Planning Phase

certain activities for the improvement of the current process structure are chosen, process controlling closely monitors the implementation of the measures chosen, in order to give a timely feedback about deviations from expected improvements.

2.6 Life Cycle Approaches to Process and Workflow Management

The continuous development of strategic goals, the design of process structures, the implementation, continuous monitoring, and evaluation/ improvement phases can be arranged to form a life cycle of process management. In the context of workflow management, several of these life cycle models have been proposed in the literature.[315]

[315] Besides the life cycles by Rolles and Heilmann, Derszteler (2000) and Galler, Scheer (1995) have presented life cycles for process and workflow management. Since these models are simpler than the ones presented here and their content is covered by the other two approaches, they have been omitted from this section.



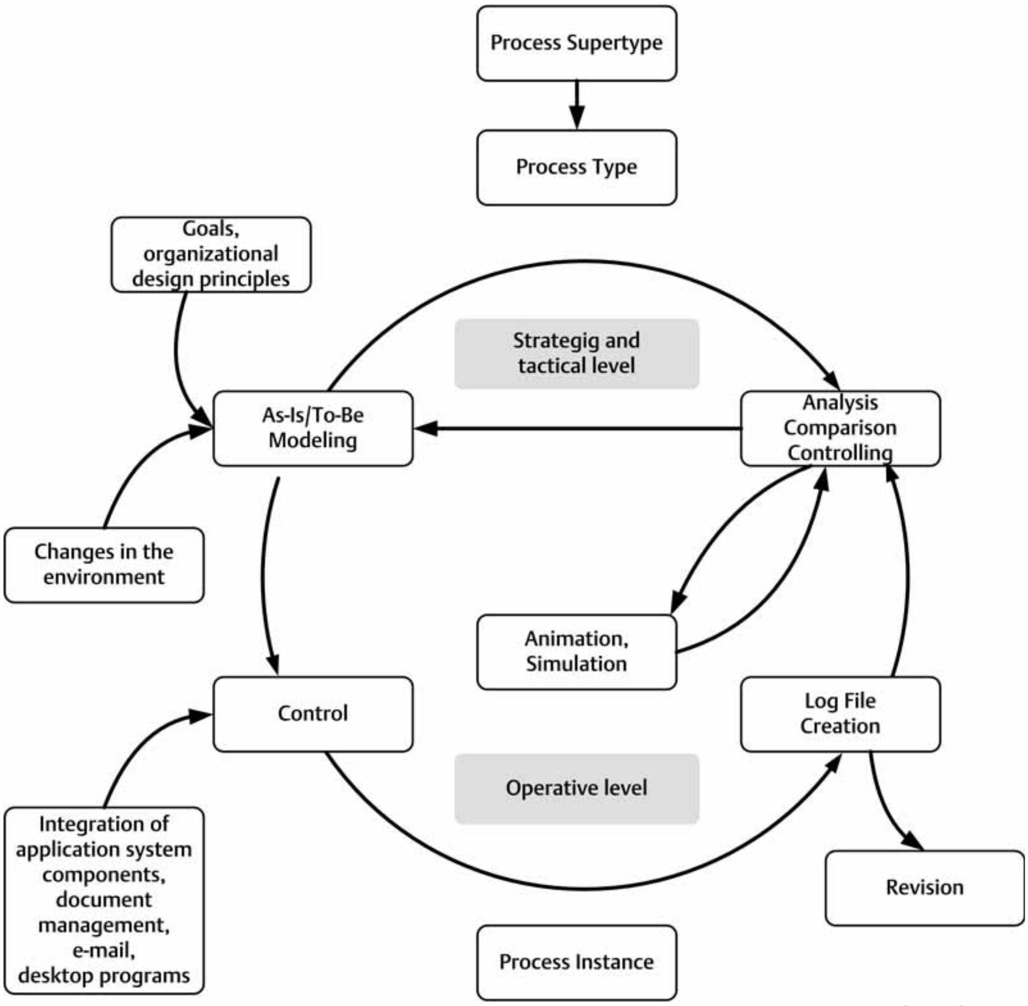
Source: Rolles (1998), p. 128.

Figure 2-15: MOVE Workflow Life Cycle

MOVE Life Cycle

ROLLES presented a procedure model developed in the context of the project MOVE (Improvement of business processes with flexible workflow management systems).[316] The life cycle is designed in three segments, starting with the evaluation and modeling of business processes. An implementation phase follows the modeling phase and is followed by the enactment phase, which can be adjusted through a flexible adjustment loop. The subsequent evaluation phase leads back to the modeling phase. The segments *technology design*, *employee orientation* and *organizational development* indicate the perspectives and goals of the phases covered under these segments. Figure 2-15 shows the MOVE workflow life cycle.

316. Compare Rolles (1998), pp. 127-129.



Source: Compare Heilmann (1997), p. 2.

Figure 2-16: Workflow Management Cycle by Heilmann

Workflow Management Cycle

The workflow management cycle proposed by HEILMANN extends the scope of activities beyond the operative implementation and enactment of workflows.[317] Instead, she separates the strategic and tactical level of process development from the operative level of workflow enactment. On the strategic and tactical level, as-is processes are modeled and analyzed using simulation and animation tools.[318] Depending on the results of this analysis, the process models may be refined, until target (to-be) models are created that satisfy the requirements of the model recipients. The partial cycle between the steps "as-is/to-be modeling" and "analysis, comparison, controlling" can be enacted multiple times. If a satisfactory process model has been designed, this model can be implemented at the operative level using a workflow management system. The "control" step denotes the enactment of

317. Compare Heilmann (1997), p. 2.
318. Refer to Heilmann (1997), pp. 1-2.

workflow instances, including the integration of external applications. Completed workflow instances are recorded in the step “log file creation” and may be sent to the corporate revision for auditing purposes. The analysis of audit trail information in the step “analysis, comparison, controlling” can lead to a new instantiation of the modeling cycle on the strategic or tactical level. Figure 2-16 shows the workflow management cycle by HEILMANN.

Review of Existing Life Cycles

Both workflow life cycles cover the analysis of the current (as-is) situation, the modeling and implementation of process models in workflow management systems, and the subsequent analysis of workflow protocol data in order to implement continuous process improvement. However, both approaches do not separate the technical implementation of the workflow infrastructure from the conceptual design of workflow models. Also, the monitoring of workflow instances during their execution and adjustments to running workflows are not addressed by both life cycle models. The feedback cycles describe work at the operative management level, but do not address, how process-relevant information can be applied to management control at the strategic level.

A Management-Oriented Process Life Cycle

A new process management life cycle is depicted in figure 2-17. It is related to the life cycle models for workflow modeling shown above, and integrates and extends the work performed by HEILMANN[319], GALLER and SCHEER[320], and STRIEMER and DEITERS[321]. Additional input was taken from the more coarse-grained process life cycle by NEUMANN, PROBST and WERNSMANN[322].

The cycle starts with an initial *analysis* of the project goals, the environment of the future workflow application, and the organizational structures and rules surrounding the new system. This phase is followed by a *process design* phase, during which the overall process structure is engineered, the process model is designed, and the resources involved in the process execution and responsible for its results are specified. This includes the modeling of organizational structures as well as the definition of task assignment policies and conflict resolution mechanisms.

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319. Compare Heilmann (1994), p. 14; Heilmann (1997), p. 2.
320. Compare Galler (1997), p. 25; Galler, Scheer (1995), p. 22
321. Compare Striemer, Deiters (1995).
322. Neumann, Probst, Wernsmann (2002), p. 308.

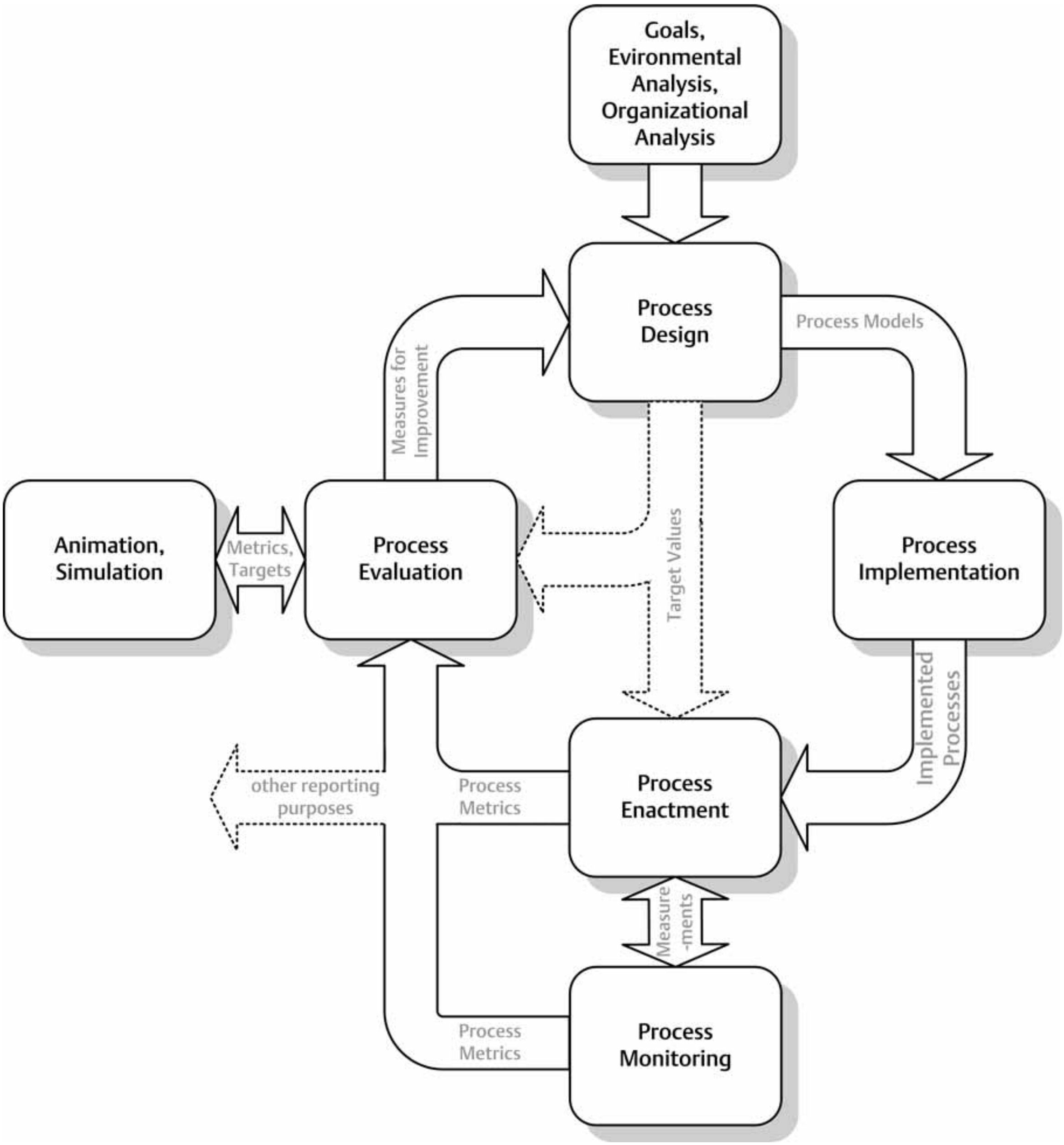

Figure 2-17: Process Life Cycle

The completed process models are input of the *process implementation* phase. During this phase, the infrastructure for business process support is designed, and the solution is integrated with surrounding information systems.

During the *process enactment* phase, individual process instances are derived from the process model and they may be coordinated by the process automation infrastructure. Process participants are notified about pending activities, and available resources are used during process execution. At the same time, from an administrative perspective, *process monitoring* takes place. On the technical side, the performance of the process management system itself is measured. On the organizational side, measures such as the length of work queues, the idle time of resources or the wait time of pending activities are supervised.

The *process evaluation* phase completes the process management cycle. During this phase, the execution of process instances is analyzed from an ex-post perspective, based on the execution protocols (audit trail). Results from this analysis can serve as the basis for the planning of resource capacities (i.e., how many performers an actual process instance needs to be staffed with). The capacity adjustments might be tested during an animation and simulation phase, where performance information from completed process instances can be used as simulation parameters. In addition, adjustments to the process structure can be tested with regard their impact on process performance.

In this chapter we have focused on the organizational aspects of process management, monitoring, and controlling. The following chapter focuses on the technical infrastructure that enables process management, monitoring, and controlling.

3 Technology Support for Process Organizations

In the previous chapter we have outlined the organizational aspects of managing business processes, and discussed the monitoring and controlling of processes from a perspective of management theory. In this chapter we focus on the technology support for process organizations that provides the infrastructure for process controlling applications. For this purpose, the chapter starts with a historical retrospective and is then organized along the process life cycle. We start with a review of the development of process automation technology in chapter 3.1, and provide an overview of the core technology concepts of workflow management and process automation in chapter 3.2. Chapter 3.3 focuses on the technical realization of workflow technology, while chapters 3.4 discuss standardization efforts in this area. chapter 3.5 focuses on the development of process-aware application systems, while the final chapter in this section focuses on the deployment and use of workflow applications.

3.1 History of Process Automation Technology

The idea of software support for corporate processes has been researched since the late 1960's. In the context of organizational theory, NORDSIECK predicted the process-oriented design of information systems:

> *"Think about [a] modern data processing [system]. This, too, represents a perceptible process that is even connected with the business process, and accompanies - or even controls - this process across various [process] segments."*[323]

At the time - the late 1960s - application development was driven by increasing volumes of data, which were of interest to different recipients inside the corporation. However, real-time access to computing technology from the desktop of the office worker was not economically feasible, even for large corporations. The idea of time-sharing computers, which allowed the end user to manipulate the data stored in the system was only addressed by researchers like DOUGLAS ENGELBART at the Stanford Research Institute, who demonstrated the prototype of an office system called NLS (oNLine System) at the Fall Joint Computer Conference 1968.[324] The first commercial efforts in the area of real-time applications was the Semi-Automatic Business Research Environment (SABRE) by IBM and American Airlines, a travel reservation system that went into production in 1960. But even

323. Nordsieck (1972), col. 9 (translated from the German original).
324. See Freiberger, Swaine (2000), pp. 303ff., and the video of the noteworthy demonstration at http://sloan.stanford.edu/MouseSite/1968Demo.html.

SABRE did not allow travel agents to connect to the system directly until 1976.[325]

The impact of computing technology on office work in the early 1970s was determined by growing database applications and the advent of end-user computing technology, where terminals were used for on-line mainframe access. However, application development was just beginning to shift from departmental-specific solutions with application-specific data storage concepts to a more modular design, where application data was stored in central databases. The business process logic was embedded in application system code and thus difficult to change. Put concisely, the aim of workflow management technology is the separation of process logic from application logic, in order to enable flexible and highly configurable applications.

JABLONSKI and BUSSLER name seven fields as the *conceptual ancestors* of workflow management technology:[326] Office automation, database management, e-mail, document management, software process management, business process modeling, and enterprise modeling and architecture. In addition to these fields, SHETH mentions distributed object management, imaging technology, transaction processing monitors, workgroup software and Internet technology as domains that are influential to workflow management technology.[327]

3.1.1 Office Automation Technology

The automation of production floor environments through production planning and -control software, which simplified repetitive tasks such as the scheduling of orders, led to significant productivity gains in the 1970's and 1980's. In contrast to these gains, the productivity of office workers had not increased, despite the deployment of information technology in office environments.[328] Fueled by the enthusiasm over increasing computing power and higher accessibility of information technology, a number of research projects emerged that studied the application of information technology to office environments.[329] The focus of office automation research was

"to reduce the complexity of the user's interface to the [office information] system, control the flow of information, and enhance the overall efficiency of the office."[330]

325. See Anthes (2004), pp. 24-25.
326. See Jablonski, Bussler (1996), p. 7 ff. The authors explicitly state that the seven conceptual influences do not constitute an exhaustive list.
327. Refer to Sheth (1997), p. 18.
328. Compare Wißkirchen (1983), p. 11, who refers to the findings of Picot (1982): "As we know, productivity gains in the area of office tasks are lagging significantly behind those in the area of blue collar work."
329. See Burns (1977); White (1977).
330. Ellis, Nutt (1980), p. 28.

The works of ELLIS and NUTT on office automation prototypes at the Xerox PARC during the late 1970s had a significant impact on the development of early office automation systems. Their systems, called Officetalk-Zero[331], Backtalk (a test environment for Officetalk-Zero)[332], Officetalk-P[333], and Officetalk-D[334] used a form-based analogy for the structuring of business processes. These processes were represented as Information Control Nets (ICN), a formalism derived from Petri Nets. The focus of the Officetalk prototype was the interaction of office workers with a graphical user interface that used common office metaphors, such as *inbox*, *outbox*, and *forms*.[335] In the outlook of one of their articles, Ellis and Nutt foreshadow the use of office automation systems for process controlling purposes:

> *"[...] an [Office Information System] might support successively higher levels of management by offering [...] the chief executive officer the ability to control and audit corporate resources."*[336]

One of the first prototype systems that supported organizational processes was SCOOP (System for Computerization of Office Processes), developed by MICHAEL ZISMAN. SCOOP was an office automation system that used Petri Nets to represent business processes.[337] His augmentation of Petri Nets supported the multiple triggering of activities, in case the number of activity instances necessary could only be determined at run time, and deadlines, in case time constraints for activities were violated. Another language for modeling office processes was introduced by KREIFELTS in 1983. KREIFELTS predicted:

> *"[Future office systems] will rarely be the one or two-place text system. Instead, they can be imagined as a group of 'intelligent' workstations, connected via a local network. [...] Not the single activity at a workplace solves a task within an office organization, but several of these single activities that are connected through a network of customer-supplier-relationships."*[338]

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331. See the detailed description of Officetalk-Zero and its comparison to approaches like SCOOP and BDL in Ellis, Nutt (1980).
332. Refer to Nutt, Ellis (1979).
333. Refer to Ellis (1979).
334. Refer to Ellis (1982); Ellis, Bernal (1982).
335. In the outlook of their paper, ELLIS and NUTT envisioned the next generation of office automation systems: "The notion of the intelligent form [...] could be extended to allow a forms process to guide itself through various work stations and measure its own progress, utilizing the facilities of particular work stations within their own domains." Ellis, Nutt (1980), p. 57. At the same time, the technical state-of-the-art is illustrated by the following quote from the same paper: "Areas on the screen are pointed to by a cursor under the control of an x-y coordinate input device called a mouse." Ellis, Nutt (1980), p. 29.
336. Ellis, Nutt (1980), p. 57.
337. Refer to Zisman (1977), Zisman (1978).
338. Kreifelts (1983), p. 216.

The findings of KREIFELTS and his colleagues at the German GMD led to the development of the DOMINO system[339], which was later used by Olivetti as the basis of the commercial X_Workflow system.[340] While most office automation prototypes relied on Petri Net-based models for the representation of office procedures, IBM developed a Business Definition Language (BDL) as a high-level programming language for processes. BDL was supposed to enable office workers to create formal office processes on the fly, but had little success in practice.[341]

3.1.2 From Office Automation to Workflow Management

Figure 3-1 gives an overview over the historical development of office automation systems and workflow technology.[342] Research in office automation, which flourished between 1975 and 1985, laid the groundwork for the development of industrial workflow applications through the analysis of technology support for administrative processes.[343]

While the research interest in office automation ceased by the middle of the 1980s[344], the commercial exploitation of workflow technology began between 1983 and 1985. It was fostered by advances in imaging and document management technology on the one side, and enhanced e-mail systems that extended traditional point-to-point mail routing with a predefined process map on the other side.[345] From this first generation of workflow systems, only few vendors are still active, while the majority of the early players have been restructured through mergers and acquisitions, or dropped out of the market altogether.

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339. For a detailed description of the DOMINO system see Kreifelts et al. (1991) and Woetzel, Kreifelts (1993).

340. Compare Woetzel, Kreifelts (1993), p. 11.

341. Refer to Hammer et. al (1977).

342. Besides scientific prototypes, figure 3-1 shows a number of commercial systems that either had a significant impact on the marketplace or were derived from scientific prototypes. The current workflow market is extremely fragmented. For an overview of workflow vendors and their systems refer to Karl (2001), and web sites such as the Workflow and Reengineering International Association (*www.waria.com*) or the Workflow Management Coalition (*www.wfmc.org*). The current state of the workflow market versus the findings of researchers in the workflow domain were discussed by Abbott, Sarin (1994); Georgakopolous, Hornick, Sheth (1995); Alonso et al. (1997) and Du, Elmagarmid (1997).

343. See Mahling, Craven, Croft (1995) and Nutt (1996).

344. Compare Swenson, Irwin (1995).

345. Examples systems within this category are Beyond Corporation's BeyondMail (which was bought by Banyan in 1995 and discontinued 1998), JetForm (now Accelio Corp.) and PowerWork. Most e-mail based systems rely on an external e-mail and messaging systems, which they enhance with routing and task assignment functionality.

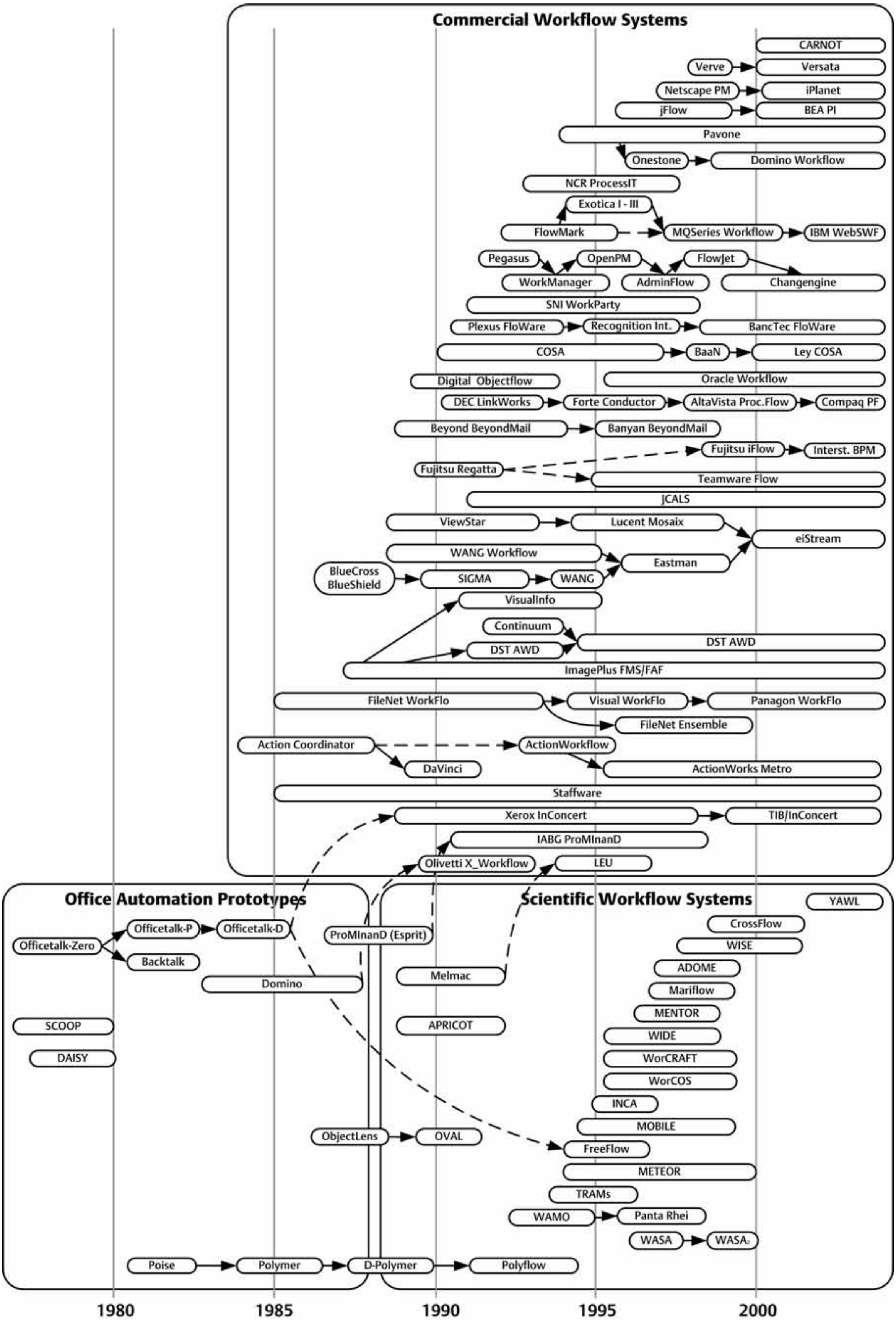

Figure 3-1: History of Office Automation and Workflow Systems

3.1.3 Other Related Technologies

BECKER and VOSSEN have pointed out three areas that were influential for the development of workflow management systems.[346] As an extension of electronic mail systems, workflow management systems enable the fast communication and collaboration between geographically dispersed users along a common workflow model. In addition, workflow management systems have similarities with active database systems that monitor the state of a system and trigger activities upon these events.[347] Finally, workflow management systems are related to federated databases and extended transaction concepts, since - from the perspective of database management researchers - a workflow can be perceived as a long-running transaction and requires sophisticated fault handling and recovery mechanisms.[348] Besides these areas, the development of document management technology has been instrumental in the commercial success of workflow technology.

Document Management Systems

The roots of commercial workflow management systems can be traced to the design of workflow components for document management applications[349] in the mid 1980s.[350] Users like BlueCross/BlueShield and vendors like FileNet enhanced existing imaging and document storage solutions with functionality to route electronic images to the in-boxes of office workers, based on a predefined activity sequence (compare figure 3-1). Workflow management systems enhance document management systems with the ability to model approval processes, route documents based on their attributes to the right performer, and increase process transparency through monitoring functionality.[351] Many economically successful workflow projects are based on a combined workflow and document management infrastructure.[352] In recent years, the use of workflow management in document pro-

346. Compare Becker, Vossen (1996), p. 21.

347. For a discussion of workflow management systems based on these event-condition-action (ECA) rules compare Geppert, Tombros (1996); Casati et. al (1996); Kappel, Rausch-Schott, Retschitzegger (1998).

348. There is a large body of literature on the extension of database transaction concepts for workflow purposes, compare for example Georgakopolous et al. (1993); Sheth, Rusinkiewicz (1993); Rusinkiewicz, Sheth (1995); Tangt, Veijalainen (1995); Alonso et al. (1996).; Worah, Sheth (1996); Zhou, Pu, Liu (1998).

349. Document management system describes a collection of technologies, ranging from the digitization of paper documents (Scanning), the automated classification of these documents according to their content (Indexing, Optical and Intelligent Character Recognition (OCR/ICR)), the storage and retrieval of electronic documents (Archiving) to the management of these archive structures with sophisticated retrieval and indexing technologies (Document Management). Compare Bock (2001). Note that some authors use the term document management for the handling of paper documents as well. Compare Götzer et. al (2001), p. 7.

350. Compare Georgakopolous, Hornick, Sheth (1995), p. 121.

351. Compare Götzer et al. (2001), pp. 74-77.

cessing applications was extended to also cover the authoring of documents and the management of document content (e. g., the workflow management system handles the review-and-publish cycle by notifying reviewers and by monitoring deadlines).[353]

The focus of document-oriented workflow management systems is the process object (in most cases an electronic document). This view has an impact on the process modeling paradigm employed by these systems. While activity-based modeling methods represent a process as a sequence of tasks with associated performers, document-oriented workflow applications are often based on state-based modeling methods. These describe a process in form of the legal state-changes of the process object, e. g., a document that may change from drafted to reviewed to either rejected or approved.[354]

E-Mail Applications

Another predecessor of workflow technology are advanced e-mail applications.[355] While standard e-mail system realize simple point-to-point routing of messages (with one or more recipients), workflow management concepts extend this functionality to include a list of recipients that are addressed sequentially (e. g., to coordinate the editing of a document).[356] From a research point of view, messaging-based workflow systems are interesting for aspects such as evolutionary workflow modeling or the support of unstructured processes where the actual sequence of activities is determined at run time. Another facet of this type of application, messaging-based workflow, is based on the notion of a network of processing stations that are supplied with process objects in a structured way. This represents yet another modeling paradigm as opposed to the activity-oriented or process-object-oriented perspective.[357]

Database Management

Workflow management systems rely on database technology to store workflow and organization models, the current state of workflow instances, and data relevant to the execution of workflow instances. The resulting impact on the design of database management systems has initiated a num-

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352. For a survey of studies from such implementation products compare the annual award series of the Giga Information Group. Compare Fischer, Moore (1997); Fischer (1999); Fischer (EIP3) (2000); Fischer (EIP4) (2000).

353. Compare Surjanto, Ritter, Loeser (2000).

354. For example, the modeling component of the system CSE WorkFlow (now SER FloWare) relies on the state-based modeling technology. Compare Raetzsch (1999).

355. Compare Becker, Vossen (1996), p. 21.

356. For a case study compare Gebauer, Schad (1998).

357. An example for a workflow-system based on the notion of intelligent processing stations was presented by Barbará, Mehrotra, Rusinkiewicz (1996) with their INCAs project.

ber of research initiatives that analyze the use of database concepts in workflow applications.[358]

Two areas of database management have been of particular interest for workflow researchers: Transaction management and active rules. From a transaction management perspective, a workflow instance can be perceived as a long-running transaction with multiple sub-transactions (i. e., the activities).[359] Since workflow instances often interact with applications outside of the control sphere of the workflow enactment service, the failure of applications during the enactment of a workflow instance has to be taken into account. Also, since business-relevant data treated in the context of a workflow-instance is in most cases accessible to other applications as well, a workflow engine cannot lock this data from access by other applications without reducing the efficiency of the entire corporate information system.[360]

From the perspective of active database research, workflow management systems can be implemented through the specification of triggers and active rules in databases, which monitor system conditions and raise triggers upon the detection of specified events.[361] The sequence of activities would thus be implemented as a collection of database actions. The first activity would be executed upon receipt of an external trigger and would create a new event upon its completion, triggering new activities along the workflow model.

3.1.4 Commercial Use of Workflow Technology

Workflow management systems have found widespread attention since the advent of this technology in the late 1980s.[362] The Association for Information and Image Management (AIIM) estimated the worldwide revenue for workflow technologies to grow from \$4.3bn in 2000 to \$8.3bn in 2003 at a compound annual growth rate of 31%.[363] Especially in conjunction with

358. Compare for example the WIDE project as described in Grefen, Pernici, Sánchez (1999).
359. Compare Leymann, Roller (2000), pp. 20-21.
360. An example is the treatment of customer data in an order processing workflow. If the workflow engine locked the customer record from access by other applications, concurrent billing and shipping processes could not proceed, because they would not be able to access the relevant customer record. The short time span of locking phases in database systems allows measures like the 2-phase-locking protocol for consistency and integrity assurance in database applications. The long time span of workflow instance enactment, which can span days, or even weeks, requires relaxed transaction concepts to ensure the integrity of workflows. Compare Leymann, Roller (2000), pp. 20-22 and 232-282.
361. Compare Geppert, Tombros (1996).
362. Note that the increasing interest does not necessarily reflect the acceptance and use of workflow systems. Ellis and Nutt point out that “The history of workflow application in corporate America has been mixed; more systems have silently died than been successful.” Ellis, Nutt (1996), p. 141. Also compare the findings of Bair (1981) and White, Fischer (1994).
363. Compare Emery (2000).

document management technology, workflow systems are perceived as the enablers of office productivity gains through the elimination of manual routing and work distribution tasks.[364] Recently, workflow management systems have spread beyond the administrative environment and can also be found as embedded software components, which enhance existing application packages (e. g., ERP systems) as well as infrastructure components (such as application servers) with process management functionality.[365] For instance, the current infrastructure component of the SAP NetWeaver package has three process automation components: Cross-component Business Process Management for the integration of applications across system boundaries; Business Workflow for the automation of people-to-system processes within a system component; and Collaborative Workflow for the automation of unstructured, ad-hoc people-to-people processes.[366]

Although workflow management systems can increase the process efficiency of an enterprise by as much as 150%[367], they do not necessarily lead to a more flexible organization.[368] Since the introduction and deployment of a workflow-based information system architecture is a complex and time-consuming endeavor, it can be observed that - once this kind of architecture has been successfully deployed - many companies resist the urge to apply changes to the new system (an effect that can be observed at companies introducing ERP packages as well).

One frequently criticized aspect of workflow management systems is the enforcement of rigid process structures that do not offer the opportunity to adjust the sequence or the content of activities to match the actual situation at run time. One extreme example for this kind of lock in is the action workflow approach by WINOGRAD and FLORES, which represents a process as a series of speech acts between a requester and a provider.[369]

364. There are numerous publications regarding the synergies between document management and workflow technology. Compare e. g. Attinger (1996); Frappaolo (2000); Emery (2000). While the paperless office was the ultimate goal for many researchers in the 1980s, recent research has shown that due to sociological reasons the elimination of paper from office procedures is rather unlikely. Compare Sellen, Harper (2002).

365. For the distinction between embedded and stand-alone workflow products refer to zur Muehlen, Allen (2001).

366. Compare SAP AG (2004).

367. Compare Moore (2000).

368. The inflexibility of activity-based workflow models have been pointed out, e. g., by Wong, Low, Ren (1998).

369. Compare Medina Mora et al. (1994). Winograd, Flores (1996) provide the formal foundation for the underlying speech act model.

Each of these conversations follows a cycle of four phases:

- Preparation: During this phase a customer asks a performer to provide a specific service.
- Negotiation: During this phase customer and performer negotiate the conditions of service fulfilment, such as quality aspects and the due date.
- Performance: During this phase the performer creates the negotiated service. The performer can ask other performers to provide parts of the overall service. During these interactions the performer takes on the role of a customer for the fulfilment of sub-services.
- Acceptance: During the final phase of the cycle the result of the service is inspected by the customer and either accepted or rejected.

SUCHMAN argues that activities are performed *in situ* and the design of future activities depends on the actual execution of previous activities, thus making an a priori process design at a fine level of detail impossible.[370] Instead, she proposes the specification of processes as situated actions. SCHMIDT - in the tradition of SUCHMAN - uses the metaphor of *maps* and *scripts* for process specifications. [371] Process models are consulted as maps if members of the organization do not know how to handle a specific situation. They are used as scripts if process participants have to adhere to a particular sequence of activities at all times. Following this metaphor, most workflow management systems rely on the scripting of processes, while most Groupware applications rely on representing processes as maps. Which of these two extremes is applicable in a given situation depends - among other factors - on the organizational context, the attributes of the process in question and the corporate culture of the surrounding organization.

3.2 Workflow Application Concepts

In this section we establish the basic terminology used for workflow applications in this book. After a review of the relevant terminology and the definition of different perspectives that can be applied to the analysis of workflow applications, we discuss two particular aspects of workflow applications: Coordination and integration.

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370. Refer to Suchman (1987) and her criticism of the action workflow approach in Suchman (1994) and Suchman (1995).
371. Compare Schmidt (1997).

3.2.1 Terminology and Definitions

"The relatively new field of workflow management systems suffers from confusion caused by weakly defined concepts and a lack of consensus about the way in which these concepts are used."[372]

This statement by JOOSTEN illustrates the state of the workflow management community at the middle of the 1990s. Due to different conceptual ancestors and the variety of workflow-related technologies, terminology from different computer science areas was used for the definition of workflow management systems and their underlying concepts. Despite the frequent use of synonyms by users and vendors (e. g., task, step, procedure, to name a few synonyms for elementary activities), the fundamental understanding of workflow management and workflow management systems has been unified in large parts by the terminology and glossary work of the Workflow Management Coalition (WfMC).[373]

Based on the discussion of the term process in chapter 2, we have defined a *workflow* in section 2.2.2 as a specific representation of a process, whose formal coordination mechanisms between activities, applications, and process participants can be controlled by an information system, the so-called workflow management system.

A *workflow management system* is defined by the WFMC as:

"A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications."[374]

Per this definition, a workflow management system consists of a modeling component for the creation of workflow models, functionality for the creation of workflow instances from these workflow models, and functionality for the execution of these workflow instances.[375] The functional component for the enactment of workflow instances is called *workflow engine*.[376] The engine metaphor has been criticized by a number of authors, as it implies that the core functionality of a workflow management system is concentrated around one monolithic application. Instead, the critics point out, the functionalities described above can be supplied by different services that

372. Joosten (1996), p. 2.
373. Compare WfMC (Glossary) (1999).
374. WfMC (Glossary) (1999), p. 9. The WfMC names the terms workflow automation, workflow manager, workflow computing system, and case management as possible synonyms.
375. Within this book, the terms workflow model and process definition are used as synonyms.
376. Compare WfMC (Glossary) (1999), p. 73, where a workflow engine is defined as "a software service [...] that provides the run time execution environment for a process instance."

may be implemented at different locations. It is important to note that a workflow management system is typically composed of a workflow engine (no matter how it is implemented) as well as additional components, such as modeling environment, run time clients, and administration components.

A *workflow model* is defined by the WFMC as:

"The representation of a business process in a form which supports automated manipulation, such as modeling, or enactment by a workflow management system. The process definition consists of a network of activities and their relationships, criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated IT applications and data, etc."[377]

This definition is limited to activity-based process modeling. Alternative approaches to workflow process modeling are presented in section 3.5.2. The restriction to business processes is an unnecessary limitation, since workflow management systems can also be applied to the automation of software processes.[378] From a functional perspective, the main tasks of a workflow management system can be grouped into planning, implementation, enactment, and evaluation of workflows. The planning and implementation phase are also called build time phase, while the enactment and evaluation phase are considered as run time phase.[379] Figure 3-2 depicts the functional decomposition of these four phases.

During the *planning phase* the conceptual model of the process to be automated is created, and organizational responsibilities as well as the links to external applications that are invoked during activity execution are specified. The data model of the information that is passed along the activities is designed during this phase as well. Finally, target values and measurements for the duration of activities and processes are determined, as is the behavior of external systems the workflow management system interacts with.

In the *implementation phase* the conceptual workflow model is transformed into an executable representation. Some systems require a translation, since their internal representation of the workflow model and the representation used by workflow modelers are different. Other systems rely on a shared database for the modeling and execution phases, and their executable workflow models are identified by an attribute. On a technical level, the interfaces to external systems need to be implemented at this stage in order to realize

377. WfMC (Glossary) (1999), p. 11.
378. Compare Gruhn, Deiters (1994); Gruhn, Wolf (1995).
379. Compare Leymann, Roller (2000), pp. 62-63; The Workflow Management Coalition uses the terms process definition mode and process execution, respectively. Compare WfMC (Glossary) (1999), p. 31 and p. 66.

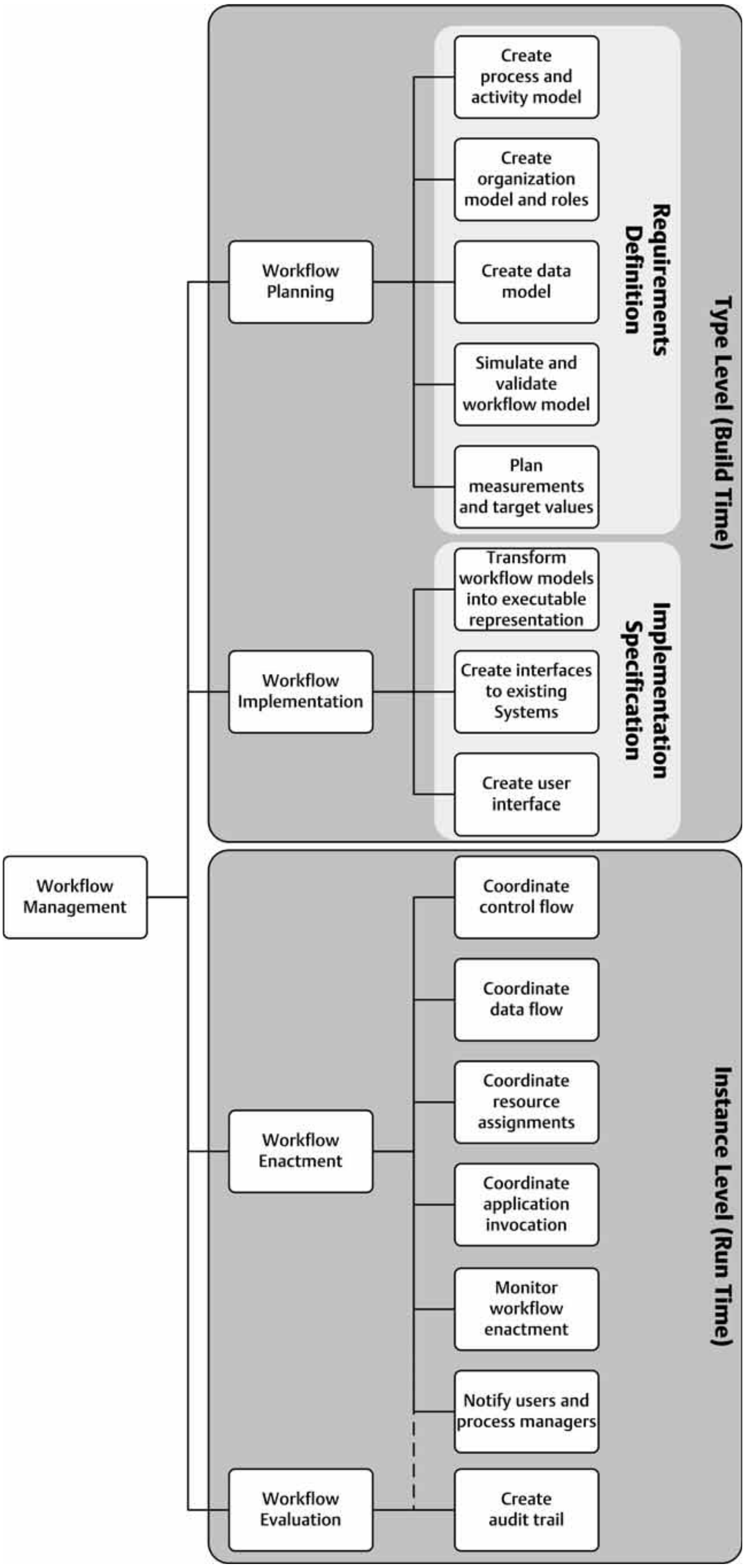

Figure 3-2: Functional Decomposition of Workflow Management

the communication between the workflow management system and invoked applications as well as front-end systems used for user interaction.

The *enactment phase* refers to the instantiation and execution of a single workflow instance from a previously defined workflow model (this instance is sometimes called a workflow case). The workflow engine coordinates the control flow by regulating the activation and execution of activities depending on the state of the overall process. It coordinates the data flow by transferring (and transforming, eventually) relevant data objects between activities and between the workflow system and invoked applications. The coordination of resource assignments relates to the identification and notification of workflow participants about pending activities by the workflow management system. The overall integrity of workflow instances is monitored by the workflow management system, i. e., escalation procedures are triggered if deadlines are exceed, and information about the current state of workflow instances is provided to interested parties (e. g., customers that inquire about the status of an order).

As part of the *evaluation phase* a workflow management system creates an audit trail which contains information about the behavior of the system and the execution of workflow instances. This functionality can also be part of the enactment phase, since audit trail information can be used for the identification of workflow participants (e. g., to reroute an activity to the performer of a previous activity).

By taking the functional decomposition of workflow management into account, we can define a workflow model as the conceptual representation of a process, specified in a manner that allows the automated coordination of activities, applications, process participants, and process objects through a workflow engine. This representation can be graphical or text-based. An *external workflow model* is specified using a modeling language readable for the human workflow modeler. An *internal workflow model* is represented in a language which can be interpreted by a workflow engine. Both models may be represented using the same language, if this language fits both purposes.

A *workflow instance* is an individual representation of a process based on a workflow model, which is enacted by the workflow engine.[380] The activity models of the workflow model are represented as *activity instances.* Workflow participants are notified about pending activity instances through representations of these instances that are called *work items.* Each workflow partici-

[380]. Compare WfMC (Glossary) (1999), p. 18.

pant is associated with one or more *work lists*, which serves as a repository for work items assigned to this participant.

A *workflow application system* (or workflow-based application) is an application system which uses (in whole or in part) a workflow engine for the coordination of application components, users, data, or parts thereof. It consists of one or more workflow engine(s), invoked applications, administration components, user interfaces, and related data stores.

3.2.2 Perspectives on Workflows

A separation of views is necessary for the analysis of workflows and workflow-based applications, in order to reduce the complexity of the system analyzed. We can apply a number of frameworks for this purpose, starting with the ARIS framework, which was introduced in section 2.2.5. Another framework that supports the separation of views is the Computer Integrated Manufacturing Open Systems Architecture (CIMOSA), which was presented by VERNADAT.[381] The CIMOSA architecture distinguishes between function, information, resource, and organization views. The intention of the CIMOSA consortium - to provide an integrating infrastructure for the execution of enterprise models - is closely related to the intention of workflow management systems - to provide an integrating infrastructure for the execution of process models. The generic building blocks of the CIMOSA architecture are shown in table 3-1.[382]

	Function View	Information View	Resource View	Organization View
Requirements Definition	■ Domains ■ Domain Processes ■ Business Processes ■ Enterprise Activities ■ Events	■ Enterprise Objects ■ Object Views ■ Object Relationships ■ Information Elements ■ Integrity Rules	■ Capabilities	■ Responsibility ■ Authority
Design Specification	■ Specified Functional Operations	■ External Schemata ■ Conceptual Schemata ■ Integrity Constraints ■ Database Transactions	■ Specified Capabilities ■ Specified Resources ■ Specified Resource Units	■ Organization Units ■ Organization Cells
Implementation Description	■ Implemented Functional Operations	■ Implemented External Schemata ■ Internal Schema ■ Logical Data Schema ■ Physical Data Schema	■ Implemented Capabilities ■ Implemented Resources ■ Implemented Resource Units	■ Implemented Organization Units ■ Implemented Organization Cells

Table 3-1: CIMOSA Generic Building Blocks

381. Refer to Vernadat (1996); ESPRIT Consortium AMICE (1993).
382. Refer to ESPRIT Consortium AMICE (1993), p. 53.

A framework of different perspectives for workflow analysis was presented by JABLONSKI and BUSSLER as part of the conceptual design surrounding the MOBILE workflow management system.[383] They distinguish between the mandatory perspectives function, operation, behavior, information, and organization. These perspectives can optionally be enhanced with views covering the causality, integrity and failure recovery, quality, history, security, and autonomy of the workflow.

Each view is separated into a factual perspective and a systemic perspective. *Factual perspectives* contain entities that exist independent of an actual workflow implementation, i. e., they relate to the complete specification of a workflow model which may or may not be automated. *Systemic perspectives* relate to the implementation of a workflow model in the context of a specific workflow management system. They contain information pertinent to the technical realization of a workflow. An example for this separation is the treatment of information about completed activities. From the factual perspective, this information is relevant for auditing and process controlling purposes; from the systemic perspective, this information may be used to determine the behavior of activities at run time (e. g., if an activity has to be executed by the manager of another activity's performer).

Function Perspective

The function perspective contains a static description of the functional entities the workflow model is composed of, i. e., the workflow process itself as well as atomic and complex activities, which form a tree with the workflow process as the root element.[384] This view corresponds to the function view of the ARIS framework as well as the function view of the CIMOSA framework.

Operation Perspective

The elements of the operation perspective describe the implementation of the workflow activities, i. e., the business functionality that is performed during the execution of a workflow activity.[385] Independent (or autonomous) workflow management systems typically act as a process coordinator. They use a black-box-model of activities, i. e., they coordinate the sequence of activities, independent of the activity semantics. Nevertheless, for the

383. Compare Jablonski, Bussler (1996), pp. 118-121.

384. Compare Jablonski, Bussler (1996), p. 119; Weske, Vossen (1998), pp. 363-364.

385. Leymann and Roller state that "building an activity implementation is sometimes called *programming in the small*. All low-level algorithmic aspects of a business function must be dealt with, data accesses must be performed, and communication with an end user must be established. Programming in the small is the traditional notion of programming." Leymann, Roller (2000), p. 218.

invocation of application programs and the presentation of data associated with an activity, the interaction of the workflow engine with existing applications and user interfaces is specified in the operation perspective.[386]

Behavior Perspective

The behavior perspective contains elements that describe the dynamic properties of a workflow process.[387] This includes the control flow between activities (i. e., the logical ordering of activities) and constructs such as loops, splits, joins, event synchronization, and triggers, which are used to refine the control flow.[388] Depending on the modeling language used, different modeling constraints have to be observed. For example, some languages demand a cycle-free graph, which prohibits the modeling of loops through control flow constructs. Instead, systems using these languages offer a specific activity type which is repeated until an exit condition is met. If the modeling language allows the nesting of processes and activities (multiple levels of processes and sub-processes), control flow loops can be represented in this way.

Information Perspective

The information perspective contains the data objects processed within the workflow as well as the data flow between different activities and data type conversions. The Workflow Management Coalition distinguishes three types of data within workflow systems:[389]

- *Application data* represents those data objects that are manipulated by the external applications during the enactment of a workflow instance. This type of data is typically not accessible to the workflow management system. An example for application data is a document that is created by a workflow participant using a word processing application. If the content of documents is not relevant to the control flow of a process, these documents are regarded as application data.

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386. Compare Weske, Vossen (1998), pp. 366-367.

387. Compare Jablonski, Bussler (1996), p. 120; Weske, Vossen (1998), p. 364. The specification of the workflow model is called *programming in the large* by Leymann and Roller. “Specifying a process model has many aspects in common with programming. Input and output structures of activities are defined, control and data flows between the various activities are furnished, and transaction boundaries are established. This kind of programming is sometimes called *programming in the large*, because it does not deal with low-level algorithmic aspects of an application but specifies “what happens when” in the overall environment.” Leymann, Roller (2000), pp. 217-218.

388. For a discussion of control flow elements compare Jablonski (1995), pp. 34-37.

389. Compare WfMC (Glossary) (1999), pp. 53-56.

- *Workflow relevant data* is used by the workflow management system to determine the control flow (i. e., transitions between activities) and may be passed between workflow management systems and invoked applications. *Typed* workflow relevant data is encoded in a format that can be interpreted by the workflow engine. Using typed data, field values can be used to determine the control flow or the responsible workflow participant for an activity instance.[390] *Untyped* workflow relevant data is treated as a black box by the workflow engine and passed from one activity to the next. This type of data can be found in software process applications where the workflow engine performs automated routing of data between application systems.

- *Workflow control data* is produced by the workflow engine itself and is not accessible to invoked applications. This type of data represents information like the state of workflow instances and activity instances, current resource assignments, users logged on to the system, and so forth. If a workflow engine is embedded in a larger application, workflow control data may be made available to the surrounding application through application programming interfaces (APIs). Workflow control data is typically the source of audit trail information.[391]

Organization Perspective

The organization perspective addresses the assignment of activities to organizational resources. Entities within this perspective include workflow participants[392], organizational structures (e. g., departments or responsibilities), and roles (e. g., manager, clerk, auditor). Roles are used as a proxy between actual system users and the activity specification, to foster the independence between the workflow model and the organization structure. At run time, the workflow engine determines system users that are members of the specified role and notifies them about the pending activity instance. This process is called *staff resolution*.[393]

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390. An example for typed workflow relevant data is a customer number passed along the activities. If the relationship between customers and customer representatives is encoded in the organizational model, the workflow engine can assign the activity instances automatically to the responsible agent depending on the value of the attribute “customer number”.

391. The WfMC states that “workflow control data may be written to persistent storage periodically to facilitate restart and recovery of the system after failure. It may also be used to derive audit data.” WfMC (Glossary) (1999), p. 56.

392. A workflow participant is a resource which performs an activity. Resources can be human resources or technical resources, such as software agents. Compare WfMC (Glossary) (1999), p. 20.

393. Staff resolution is discussed in detail in section 3.5.4 on page 160.

Causality Perspective

The causality perspective describes under which conditions a workflow can be executed. On the one hand, this information may provide a process context necessary for the workflow performers' actions. On the other hand, a workflow system may monitor the environmental conditions and abort running workflow instances, if the causality for their execution is no longer given.[394]

Integrity and Failure Recovery Perspective

The integrity and failure recovery perspective contains elements that relate to the correct execution of a workflow instance. These elements provide information which can be used by a workflow management system to determine whether a workflow instance or activity instance has been completed successfully or not. If a workflow instance or activity instance fails, predefined procedures for the maintenance of a consistent system state can be executed.

The elements of this perspective mainly fall into two categories: *Transaction-related concepts* and *error handling concepts.* Transaction-related concepts apply elements from database transaction management to the handling of workflow and activity instances, such as the definition of a transaction context and compensation activities in case of transaction failures.[395] Error handling concepts relate to the management of unexpected situations during the execution of a workflow.[396] This can range from recovery procedure definition[397] to organizational escalation handling mechanisms, if workflow instances or activities exceed deadlines.[398]

Quality Perspective

The quality perspective is used to determine whether a workflow instance has been executed in an efficient manner or not. This perspective reflects our intention to establish a workflow-based process controlling. JABLONSKI and BUSSLER restrict their discussion of this perspective to time and cost parameters, which can be evaluated either during the execution of a workflow instance (workflow monitoring) or during subsequent evaluations of completed workflow instances.[399] However, they neither elaborate which

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394. Nickerson illustrates this situation using the example of a long-running visa application process, where the applicant deceases after the application process is started. Compare Nickerson (2003).

395. Compare for example Worah, Sheth (1996).

396. Compare for example Casati (1998); Casati, Fugini, Mirbel (1999).

397. Compare for example Kiepuszewski, Muhlberger, Orlowska (1998).

398. Refer to Panagos, Rabinovich (1996).

methods should be used for the evaluation of this information; nor do they provide guidelines, which quality attributes should be recorded during workflow execution.

History Perspective

The history perspective relates to the events recorded during the execution of workflow instances. These events comprise the so-called audit trail, and provide detailed information about the actual sequence of activities executed, the resources which performed the activities, (key) attributes for the workflow instance, and so forth.[400] The history perspective has two possible applications. On the one hand, it can be used for system recovery purposes, in order to establish the last known process state after a system failure.[401] On the other hand, it provides source data for the analysis of the technical and economical performance of the workflow management system.[402]

Security Perspective

The security perspective addresses access control aspects of a workflow application.[403] One of the biggest obstacles during the development of a workflow application is the seamless integration of activity-based access control regulations and application-based access control aspects. Access to activity instances is controlled through the specification of users and roles in the organization perspective. If this information is not aligned with the access rights to invoked applications, users may be granted access to activities which they cannot perform, because they do not have the corresponding access rights at the application level.[404]

Autonomy Perspective

The autonomy perspective covers the mobility aspect of workflow applications.[405] In a mobile environment, users may be able to connect to a workflow management system using mobile devices, such as web-enabled cell phones or personal digital assistants. In this case the workflow management system may not be able to synchronize the work list of a user continu-

399. Refer to Jablonski, Bussler (1996), p. 188.
400. Compare Jablonski, Bussler (1996), pp. 120-121.
401. An example of such a recovery procedure is given by Kiepuszewski, Muhlberger, Orlowska (1998).
402. Refer to McLellan (1996).
403. Compare Jablonski, Bussler (1996), p. 121.
404. For a detailed discussion of security constraints and access control compare Bertino, Ferrari, Atluri (1999).
405. Refer to Jablonski, Bussler (1996), p. 121, who use this perspective to cover mobility (of workflow components), distribution (of activities or process parts, i. e., the execution over a network at a remote location) and execution threads (i. e., the synchronous or asynchronous invocation of sub-workflows or applications).

ously.[406] In addition, users may have the requirement to check-out workflow instances and activity instances, work remotely on their completion, and check them back in at a later point in time.[407]

Comparison of the different frameworks

The different views found in ARIS, CIMOSA, and MOBILE are summarized in table 3-2. While ARIS and CIMOSA distinguish between views and phases, the MOBILE model only distinguishes different perspectives. The table refers to the requirements definition phase of ARIS and CIMOSA, unless stated otherwise.

<table>
<tr><th></th><th>ARIS</th><th>CIMOSA</th><th>MOBILE</th><th>Entities</th></tr>
<tr><td rowspan="7">Factual Perspectives</td><td>Data</td><td rowspan="2">Information</td><td rowspan="2">Information</td><td rowspan="2">Data Types
Data Objects
Data Flow</td></tr>
<tr><td>Output</td></tr>
<tr><td>Function</td><td rowspan="2">Function</td><td>Function</td><td>Activities</td></tr>
<tr><td>Control</td><td>Behavior</td><td>Control Flow</td></tr>
<tr><td>Organization</td><td>Organization</td><td>Organization</td><td>Participants
Roles
Groups</td></tr>
<tr><td>Function
(Implementation)</td><td>Resource</td><td>Operation</td><td>Invoked Applications
Software agents</td></tr>
<tr><td rowspan="6">Systemic Perspectives</td><td>Control</td><td></td><td>Causality</td><td>Goals
Global Conditions</td></tr>
<tr><td>Control
(Implementation)</td><td>Function
(Implementation)</td><td>Integrity and
Failure Recovery</td><td>Consistency constraints
Dependencies
Compensation procedures</td></tr>
<tr><td>Function
(as attributes)</td><td></td><td>Quality</td><td>Time and cost measurements</td></tr>
<tr><td></td><td></td><td>History</td><td>Log files
Workflow protocols</td></tr>
<tr><td>Organization
(Implementation)</td><td>Organization/Resource
(Implementation)</td><td>Security</td><td>Access constraints</td></tr>
<tr><td></td><td></td><td>Autonomy</td><td>Mobility information</td></tr>
</table>

Table 3-2: Perspectives on Workflow Models and related Entities

406. The same situation occurs, if users are notified by e-mail about pending work items. Only if the workflow management system can exercise control over the mail server, expired work items can be removed from the work list (in this case the inbox of the authorized user). A solution for this scenario is the provision of a proxy address from workflow participants, who select a work item. Upon activation of a work item, the participants are directed to a server-generated web page that either provides a link to the activity implementation or informs the user about the expiration of a work item.

407. For a discussion of mobile workflow applications compare Jing et al. (2000).

While ARIS offers two distinct views of data objects, both CIMOSA and MOBILE integrate these objects in the information perspective. This is consistent with the criticism of the output view, as stated in section 2.2.5 on page 53. Neither CIMOSA nor ARIS offer dedicated views for the handling of history data as well as autonomy information. Since the history aspect is significant for process controlling purposes, we apply the MOBILE framework in the subsequent sections.

3.2.3 Workflow Applications as Coordinating Systems

From a conceptual perspective, the purpose of a workflow management system is the coordination of all entities involved in the execution of a business or software process. Coordination can be defined as the management of dependencies between activities.[408] MALONE and CROWSTON have classified dependencies and related coordination processes in a framework that is shown in table 3-3.[409]

Dependency	Description	Coordination Process
Prerequisite	An activity depends on the output of another activity	Activity ordering
Shared Resource	Multiple activities require the same resource	Resource allocation
Simultaneity	Two activities must be performed at the same time	Activity synchronization
Task/Subtask	Top-level goal is dependent on the achievement of other goals	Goal decomposition

Table 3-3: Dependencies and Coordination Processes

Workflow management systems address these dependencies through their coordination functions. Prerequisite dependencies between activities are managed through the supervision of control and data flows. Shared resources are managed through scheduling and staff resolution mechanisms. Task/subtask dependencies are addressed through the hierarchical composition and decomposition of workflow models. Simultaneity constraints are observed through event-based synchronization of processes and activities. Through the automation of these coordination functions, workflow management systems support several efficiency goals of the enterprise (see table 3-4).[410]

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408. Compare Malone, Crowston (1994), p. 90. Refer also to Crowston (1994), who points out that “coordination is seen as a response to problems caused by dependencies.”
409. Compare Malone, Crowston (1990).
410. A preliminary version of this table can found in Becker et al. (1999).

Efficiency Goal	Description	Workflow Support
Process Efficiency	Optimization of process properties such as processing time (to be minimized) or adherence to deadlines (to be maximized)	Coordination of activities through control flow, alerts etc.
Resource Efficiency	Efficient use of the resources available for the execution of processes (human resources as well as application systems).	Staff resolution and reminder in case of process escalation
Market Efficiency	Proper positioning of the enterprise in its relationship to market partners. This includes a reliable prediction of delivery times, transparent communication with suppliers and customers, and optimized procurement and distribution processes.	Well defined process interfaces for web services (defined external behavior), predictable internal behavior through standardized processes
Delegation efficiency	Adequate use of the competencies of organizational units, both superior (greater scope of vision along the process) and subordinate (detailed knowledge about single activities).	Coordination of staff assignment, role concepts
Motivation Efficiency	Motivation of staff to act in a way aligned to the business goals of the enterprise.	Guidance to perform activities along a workflow model, monitoring of progress and explanation of preceding activities

Table 3-4: Efficiency Goals and Workflow Support

It is apparent that the benefits of workflow applications increase with the number of coordination tasks that can be automated through a workflow system. The number of coordination tasks varies with the granularity of the components controlled through the workflow system as well as with the type of the process controlled through the workflow system.

3.2.4 Workflow Applications as Integration Systems

Integration is regarded as one of the primary goals during information system design.[411] Literally, integration means to form, coordinate, or blend something into a functioning or unified whole by ending existing segregation.[412] Two distinct types of integration can be distinguished:[413]

- *Integration through connection* occurs if a new system is created through the creation of links between disparate, but logically connected entities or sub-systems. Typically this is an ex-post integration of existing systems, such as the integration of enterprise applications through a workflow management system.
- *Integration through combination* occurs if similar system elements are combined, thus leading to a decreased number of elements and relationships within the system (in the sense of abstraction). Typically this

411. Compare Rosemann (1999), p. 5; Heilmann (1989).
412. Refer to Merriam-Webster (2002).
413. Compare Rosemann (1998), pp. 155-165.

form of integration happens during the conceptual design phase of an information system, for example the development of a complex application with an integrated workflow layer for the transport of application data.

ROSEMANN names reduction of redundancy, increased system consistency and integrity, and better decision support through timely information supply as the main goals of integration efforts.[414] Integration can be characterized regarding the information type, object, direction, scope, and realization of integration. In terms of the dimensions of integration, data integration, function integration, process integration, and object integration can be distinguished. Integration can extend across an organization horizontally (such as cross-organizational processes), or vertically (such as reporting data flow up the organizational hierarchy).

The design of a workflow application creates integration requirements that can be differentiated into internal and external integration requirements. Internal integration requirements concern those systems a workflow application needs to be connected to, in order to ensure the functionality of the core workflow system. External integration requirements exist with regard to systems that either invoke the workflow system from the outside (embedded usage), or systems that are invoked by the workflow application.

Internal Integration Requirements

As stated above, workflow management systems coordinate activities, workflow participants, data, and applications. Consequently, all these elements need to be integrated to ensure the functionality of the workflow systems.

- *Resource integration* is required by the workflow system to keep track of the participants available for activity assignment. Since many companies maintain resource information in organizational directories or similar applications, a fully integrated workflow application would use this information rather than replicate resource data in an internal data store.
- *Data integration* is required to make workflow relevant data accessible to the workflow system. This can be achieved by connecting the system to databases used by external application systems. If the workflow system acts as an enterprise application integration hub, conversion of data types and attribute values may be necessary.

414. See Rosemann (1998), p. 156.

- *Application integration* describes the ability of the workflow system to invoke external application systems during the enactment of a process. For organizational processes, applications are often called in their entirety (e. g., a word processing application), while for software processes the granularity of application invocation is at method or function level.

In addition to these three integration requirements, the use of existing security infrastructures is another important feature of workflow applications.

- *Security integration* relates to the use of existing authentication and authorization mechanisms through the workflow system, such as single-sign-on and public key infrastructures.

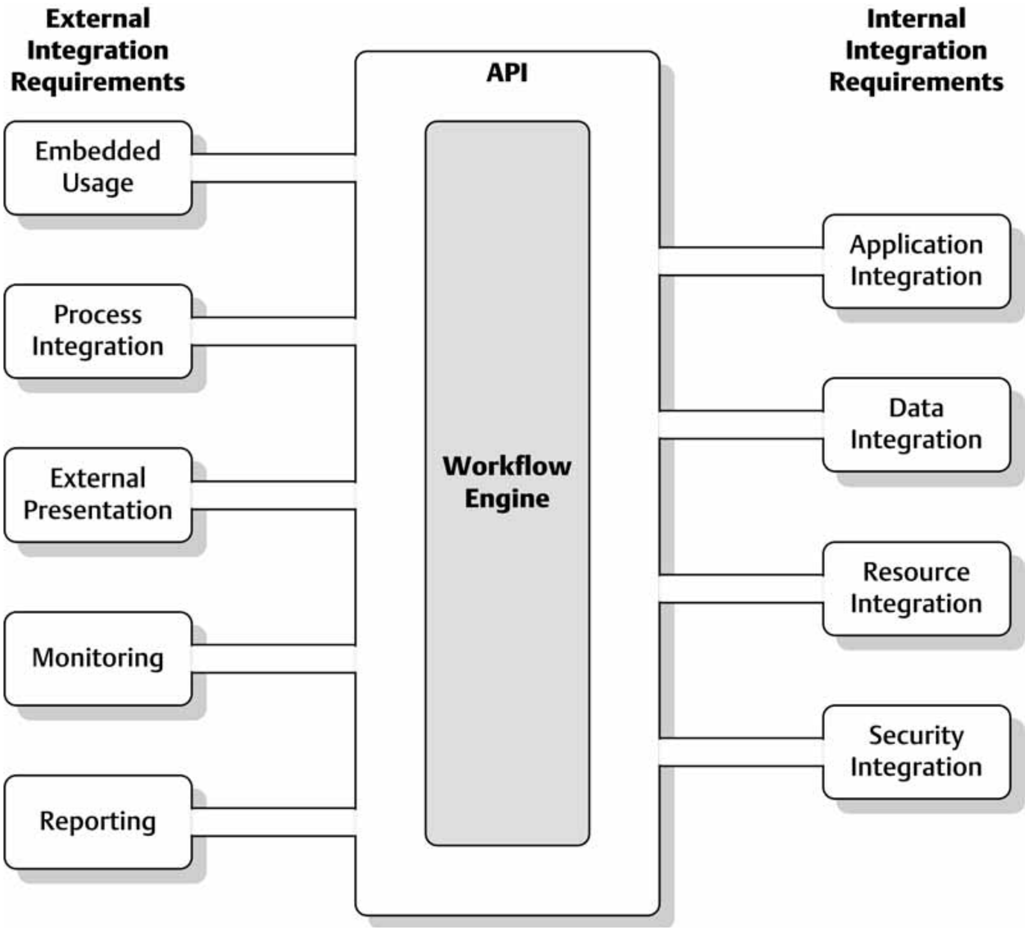
External Integration Requirements

The external integration of a workflow system relates to the fact that a workflow system is an application system in its own right. External applications may require calling the services of a workflow engine from the outside, invoking workflow instances, querying the status of activity instances, or handling resource assignments through external scheduling mechanisms. In addition, the workflow system may be required to present work to outside parties that are not direct users of the workflow application.

- *External invocation* of the workflow engine is used, for example, in B2B process integration. The workflow engine can exhibit its functionality as a service to outside parties, allowing them to invoke a process and pass initial data to the process instance.[415] Examples for an external invocation are e-mail (mail daemon triggers the workflow), the web (a web server triggers the workflow), or other applications, which embed the workflow system (a function within an application results in the start of a workflow).
- *Presentation of information* to outside parties is necessary, if the workflow system has to notify external participants about the status of "their" workflow instances, or if system load information is passed on to external system management tools. Also, the use of audit trail information through external applications falls into this category.

415. This invocation model has been formalized in the Wf-XML specification by the Workflow Management Coalition, and the ASAP (Asynchronous Service Access Protocol) specification by OASIS, which represents a revised version of Wf-XML. See WfMC (Wf-XML) (2001); Ricker et al. (2003).

Figure 3-3 summarizes the internal and external integration requirements of workflow applications.



Source: Modified from Becker, zur Muehlen, Gille (2002).

Figure 3-3: Workflow Integration Requirements

3.3 Technology of Workflow Applications

3.3.1 Technical Structure of a Workflow Management System

The structure of a workflow management systems is separated in a development environment (build time component) and an execution environment (run time component).[416] The development environment provides workflow designers with tools for the design of workflow models, the specification of workflow relevant data structures, and the design of the organizational model relevant to the execution of the workflow models. While the modeling of processes and organization structures are often supported through graphical modeling tools, the specification of data structures and integration adapters is mostly text-based and resembles a traditional programming environment.

416. The design discussed in this section represents a generic workflow management system and is not based on a particular system architecture.

A textual representation of workflow models that can be instantiated in the run time environment is stored in a workflow model repository. In some cases a translation of the workflow model into an executable format is required. While some vendors rely on proprietary formats to store their process models, the use of XML documents based on an XML schema for the representation of workflow models is increasing.[417]

The organizational model, i. e., the list of users, their relationships and associated roles, as well as organizational units, is either stored with the workflow model in the same repository, or stored in and accessed from a separate repository.[418]

The run time environment of a workflow management system (i. e., the workflow engine) consists of a number of modules that cover different functional aspects. These modules are typically connected through a coordination entity, such as an event handler, which sends event notifications to and receives notifications from these modules.

- The *process management facility* is responsible for the creation of workflow instances from the workflow model repository and the creation of an appropriate entry in the workflow instance database. It has to observe execution constraints, for instance the validity period of a workflow model.
- The *control flow manager* handles state changes of the workflow instances and their associated activity instances.[419] It evaluates control flow conditions and creates activity instances, if the preconditions defined in the activity models are met.
- The *worklist handler* creates work items for these activity instances and manages access rights to work items. It interacts with the work lists of different users and handles conflicts, such as the concurrent selection of the same work item by two users.

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417. Examples are the FlowMark Definition Language (FDL) by IBM, the Staffware format XFR, or the XML Process Definition Language by the WfMC (compare WfMC (XPDL)(2003).

418. An example for a separate organization modeling environment is the Organization and Role Model (ORM) by Siemens-Nixdorf. Compare Rupietta (1997). Separate repositories are used frequently if the organization uses a central organization directory, which is accessed using the lightweight directory access protocol (LDAP).

419. JABLONSKI and BUSSLER define an additional module which handles the actual execution of activities and their associated applications, the *Kernel* of a workflow engine. Compare Jablonski, Bussler (1996), p. 229.

- The *user management* facility controls the access of system users to work lists and the workflow management system in general. It uses information from the organizational repository to determine the workflow participants covered by a particular role.
- The *application invocation* module manages the interaction of the workflow engine with invoked applications. It monitors return codes from external applications to determine the successful completion of activity instances and passes data to and from invoked applications.
- The *data management* component performs data conversion and data mapping functions between activity instances.
- The *history management* component logs system events in the audit trail. These events can be either system related (e. g., user log-on and log-off) or workflow instance related (e. g., activity started, activity completed).
- *Integration APIs* provide access to the workflow engine for external systems. This allows for the embedding of the workflow engine in another application.[420]

Figure 3-4 shows the main components of a workflow management system in a schematic diagram.

3.3.2 Stand-alone versus Embedded Workflow

Depending on the application context, workflow management systems can either be “hidden” inside a workflow-enabled application system, or they can operate as free-standing applications in their own right. While most workflow solutions from the 1980s and 1990s were of the latter kind, many workflow vendors are repositioning or redesigning their products as building blocks for complex, process-aware application systems. Figure 3-5 illustrates the position of a workflow service in an integration platform scenario.

A stand-alone workflow management system is functional without any additional application software, with the exception of database management systems and messaging middleware.[421] For the deployment of an autonomous workflow solution, application systems that are external to the workflow management system are invoked at run time and workflow relevant data is along the workflow participants. Stand-alone workflow management

420. A popular requirement for embedded usage is the creation of a workflow instance from a web page. In an e-commerce application, the completion of an on-line form creates a database entry with the entered field values and an instance of the associated workflow model is created through the web server, which uses the workflow engine API.

421. Compare zur Muehlen, Allen (2000), p. 49.

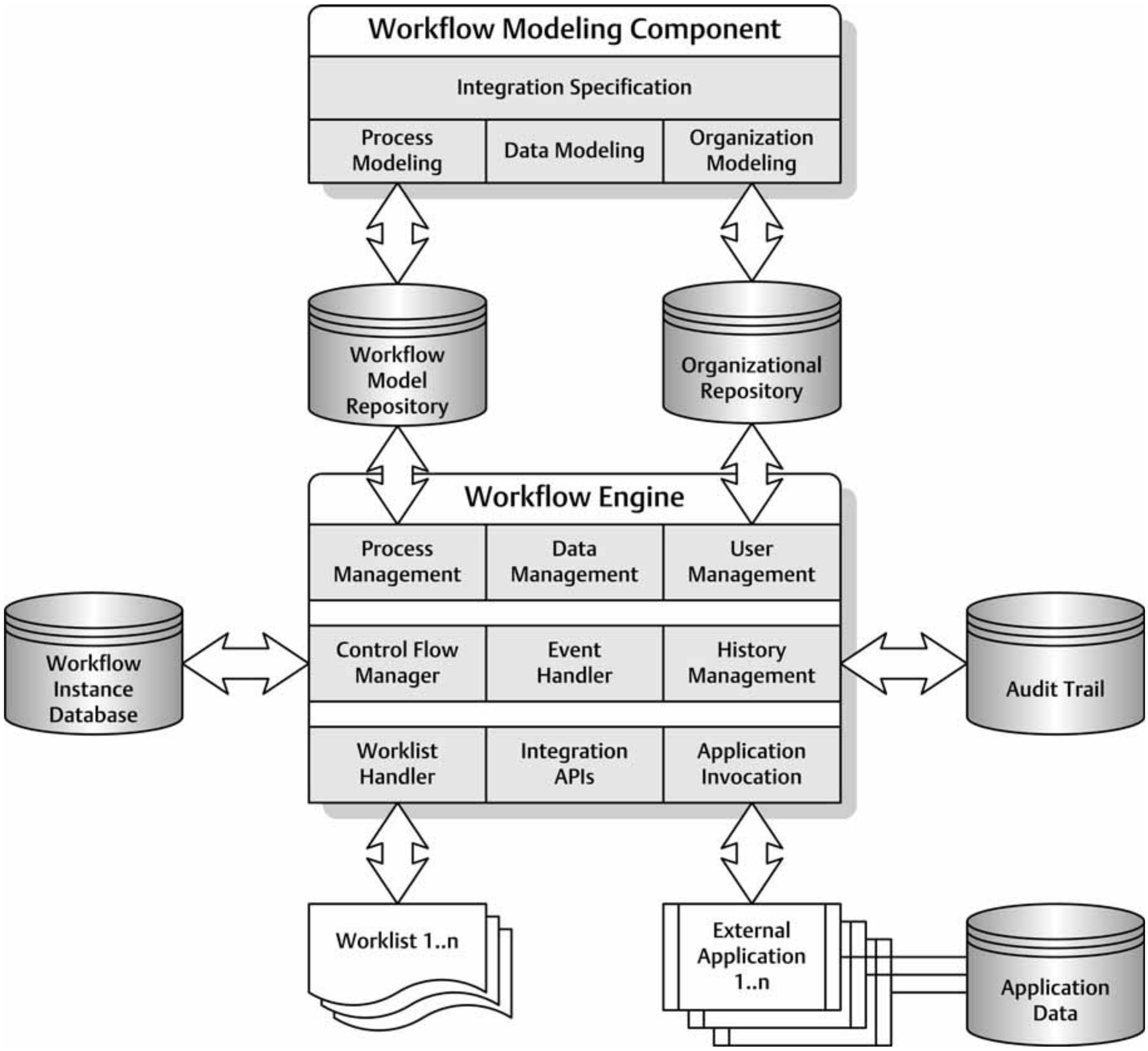

Figure 3-4: Technical Structure of a Workflow Application

systems typically provide their own user interfaces (i. e., a proprietary worklist handler) and will access data from other applications. They are usually installed to support a variety of different applications.

An embedded workflow management system is only functional if it is deployed with the surrounding (embedding) system - for instance, an Enterprise Resource Planning (ERP) system.[422] The workflow functionality of embedded workflow management systems is used by and exhibited to the surrounding software system. Common examples include ERP and CRM systems as well as content management applications. The workflow components are used to control the sequence of application functions, to manage work queues, and to assist with exception processing.

422. For a comparison of embedded workflow management systems within ERP systems compare Becker, Vogler, Österle (1998).

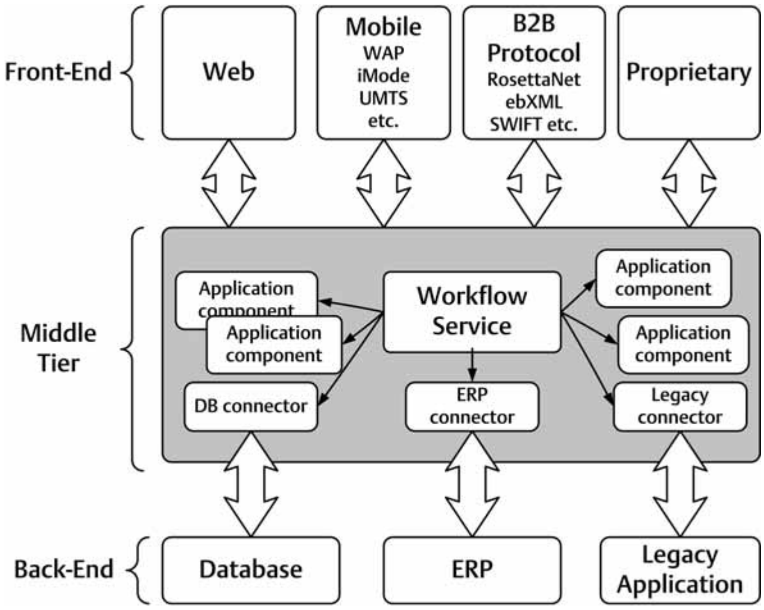

Figure 3-5: Workflow Services as Integration Technology

Embedded systems can be classified into two distinct categories. *Workflow-based* solutions are not functional without the built-in workflow functionality, while *workflow-enabled* systems leave it to the discretion of the system user, if the built-in workflow component is applied in a given context.[423]

3.4 Standardization Efforts in the Workflow Area

The increasing use of workflow management components as building blocks for application software architectures as well as the use of workflow systems embedded in larger application systems, such as ERP packages, ultimately leads to the coexistence of several workflow management systems within an organization. Since these workflow systems have to be integrated into the existing information system infrastructure, the standardization of integration interfaces promises reduced implementation times, and better reuse of workflow components. In the field of cross-organizational workflow management, the standardization of invocation interfaces and messaging formats improves the development of plug-and-play solutions and reduces the risk of using proprietary technology for the participants of a B2B process. The following section presents an overview of standardization initia-

423. An example for a workflow-enabled solution is the NetWeaver integration platform by German software vendor SAP AG. Its workflow components Business Workflow, Cross-Component BPM and Collaborative Workflow are standard components delivered with every SAP NetWeaver installation. While Business Workflow is used for some software processes, it is possible to use the NetWeaver package without explicit usage of the other two workflow components. Compare SAP AG (2004). On the other hand, the Cheops system, a customer care information system for public utility enterprises, was designed as use-case-oriented application modules that were linked through a common workflow layer (ifs Univoss, compare ifs GmbH (2001)). Without this workflow layer, the Cheops system would not have been functional. Compare Thompson (2000).

tives in the field of workflow management and discusses standards that are relevant to the development of process controlling systems.[424]

3.4.1 Workflow Management Coalition (WfMC)

Faced with a growing number of workflow products, each of which used its own proprietary terminology, a group of large software users organized in the Black Forest Group chartered a number of workflow vendors with the task to develop interoperability standards in mid-1993. Following this challenge, an initial group of vendors and consultants founded the Workflow Management Coalition (WfMC) in August 1993. Membership of the WfMC is comprised of more than 250 vendors, users, consultants, and research institutions with an interest in the field of workflow management. The members are grouped into funding members, who may vote on the approval and publication of standards proposals, and guest members, who may participate in WfMC meetings, but have no voting rights. The WfMC standards are recommendations for workflow vendors, but there is no obligation for participating members to actually implement the standards. Also, there is currently no formal conformance testing for standards adherence in place, i. e. vendors who claim to support WfMC standards have not submitted their products to an independent conformance evaluation.

Formal Structure of the WfMC

The WfMC is organized in three committees:

- The *Technical Committee* (TC) is responsible for the definition of technical WfMC standards and submits standards proposals to the Steering Committee for approval and publication. The TC is organized in working groups which focus on particular aspects of workflow interoperability, such as the administration and monitoring interface, or the XML process definition standard XPDL.[425]
- The *External Relations Committee* (ERC) is the public relations arm of the WfMC. It is responsible for the publication of approved WfMC standards and the issuing of press releases about WfMC activities. The ERC has a number of country contacts who report on regional developments of the workflow market and serve as contact persons for membership prospects.

424. This section is intended as an overview of standards groups and their activities. For a critical discussion of standardization efforts in the area of workflow, and particularly web services choreography, compare Nickerson, zur Muehlen (2003), and zur Muehlen et al. (2004).

425. Both of these standards will be discussed later in this chapter.

- The *Steering Committee* (SC) is the management organization of the WfMC. The elected officers (chairperson, treasurer, secretary, general manager) lead the SC and coordinate the work of ERC and TC. For instance, they make sure that forthcoming standards are announced by the ERC, and that the TC provides the ERC with sufficient documentation for publication purposes.

WfMC members meet three times a year, and use telephone conferences between meetings to advance the standards development process. Each major WfMC standard has one responsible TC working group chairperson, who coordinates the development efforts.

Relationships to other Standardization Organizations

To date, the WfMC represents the only standardization organization exclusively devoted to the standardization of workflow system interfaces. In the area of workflow modeling languages, the work of other groups has an overlap with WfMC proposals such as WPDL and XPDL. For example, BPML by the Business Process Management Initiative (BPMI), BPEL4WS by OASIS, WS-CDL by the World Wide Web Consortium (W3C) and the Workflow Facility of the Object Management Group (OMG) pursue goals similar to XPDL. The contributions of these groups will be discussed later in this section.

The WfMC has working relationships with the Object Management Group and its members have contributed to OMG standards such as the Workflow Facility.[426] It also maintains a working relationship with BPMI and OASIS, and in several instances individual members contribute to both organizations.

3.4.2 WfMC Standards

WfMC Glossary

Due to the increasing number of workflow vendors by the middle of the 1990s, vendor-specific terminology for workflow constructs led to an inconsistent vocabulary of workflow terms.[427] In order to counter this trend, the first goal of the WfMC was to establish a common terminology for workflow concepts, which led to the publication of the WfMC Terminology & Glossary.[428] Today, the WfMC glossary covers most workflow concepts and gives definitions for terms such as *activity*, *workflow management system*, or *partic-*

426. Compare section 3.4.4 page 128.
427. Compare Joosten (1996).
428. Compare WfMC (Glossary) (1999).

ipant. Although not all workflow vendors use standard terminology, the WfMC vocabulary has found widespread acceptance in practice. It is perceived as a valuable aid for the system selection process, since proprietary terms used by different vendors can be transformed to a common basis, thus enabling a comparison of systems on the basis of a single vocabulary.

WfMC Reference Model

The WfMC reference model was introduced in 1995 as a means to group workflow-relevant interfaces according to their purpose and constitutes one of the most influential workflow frameworks to date.[429] The model consists of five interfaces, which are depicted in figure 3-6. While the reference model provides a framework that illustrates the role of the different interfaces, each interface is specified through an abstract specification that describes the generic functionality of the individual interface. Depending on the functionality of the interface, one or more interface bindings are provided as illustrations how an interface can be implemented using particular languages or technologies.

All five interfaces are grouped around the execution core of the workflow management system, the *workflow enactment service*, which encapsulates one or more *workflow engines*. A system may consist of several workflow engines, e. g., if it is implemented in a distributed manner. The communication between the workflow enactment service and outside systems is provided through an application programming interface (API), the workflow API (WAPI). The WAPI is defined by the WfMC Interface 2 and 3 definition[430], with additional information provided by the other interface definitions. The following sections present the individual interfaces in detail.

WfMC Interface 1

The WfMC *Interface 1* provides a generic process description format, the Workflow Process Definition Language (WPDL).[431] The purpose of WPDL is the exchange of workflow specifications between different workflow systems, or business process modelling tools and workflow management systems. For this purpose, WPDL provides a common subset of elements found in most workflow management systems. WPDL is specified using an extended Backus-Naur Form (EBNF)[432] and a plain text description, but is independent of a particular system implementation. Due to sometimes con-

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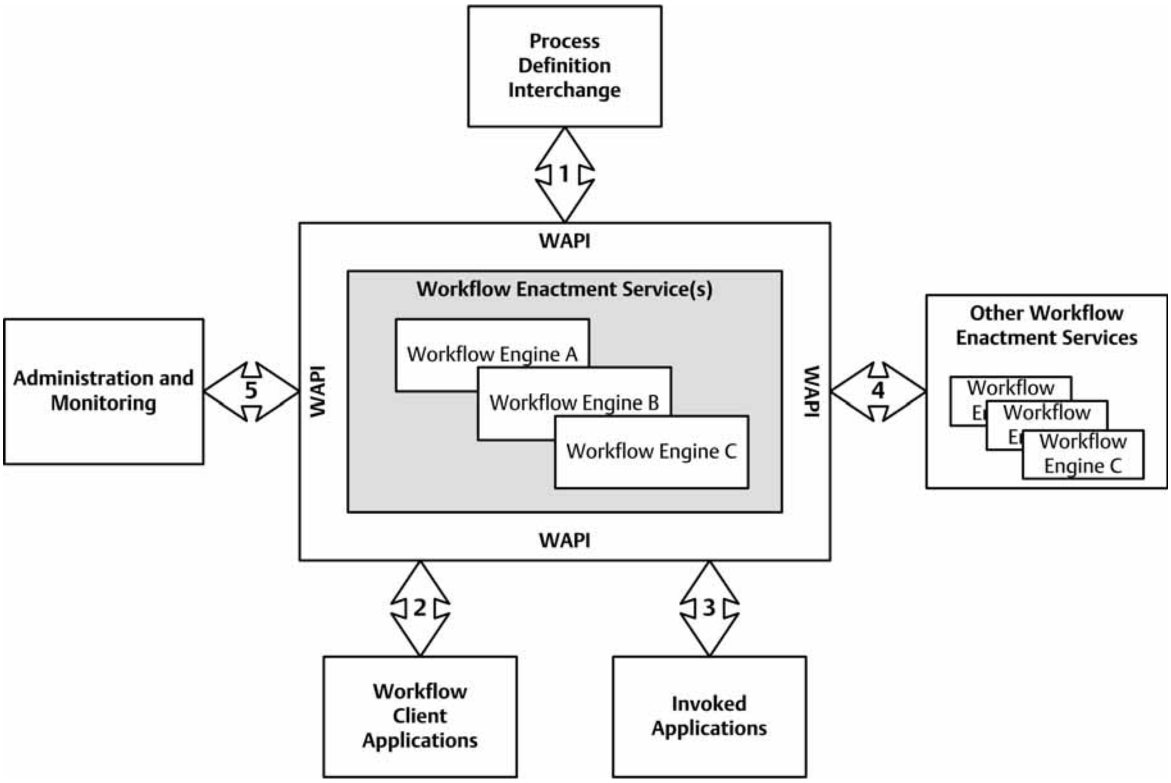
429. Compare WfMC (Glossary) (1999).
430. Compare WfMC (WAPI) (1998).
431. Compare WfMC (WPDL) (1999).
432. Compare ISO (1996).



Compare WfMC (Glossary) (1999)

Figure 3-6: Workflow Management Coalition Reference Model

flicting modeling concepts used by different workflow vendors, the unification process for WPDL turned out to be difficult. Examples for opposite ends of the modeling spectrum are Petri Net-based tools such as LEU[433] (which was based on Funsoft nets, a high-level Petri-Net type) and COSA on the one side[434], and speech-act based tools such as Action Workflow on the other side.[435]

While a number of tool vendors have implemented WPDL (some in a prototype stage), interface 1 is widely perceived to be without practical relevance.[436] In 2002 an XML representation of WPDL called XPDL was published, which has been implemented in a number of open-source workflow projects.[437] To date, the re-use of workflow models is rarely found in practice. This may be attributed to the fact that the actual modeling of workflow

433. The workflow management system LEU originated from the research prototype MELMAC at the University of Dortmund, compare Deiters, Gruhn (1990); Gruhn, Deiters (1994). With a strong background in software process management, the system is a prime example of research prototypes that were transformed into commercial products. Commercially the system was a failure and its development ended in 1997, but the modeling environment is still marketed by adesso (www.adesso.de) under the name *LEUsmart*.

434. See, e. g., Dinkhoff et al. (1994); Gruhn, Kampmann (1996). For a comprehensive overview of Petri Net-based workflow modeling approaches refer to Salimifard, Wright (2001) and van der Aalst (1998).

435. See, e. g., Medina Mora et al. (1992); de Michelis, Grasso (1994). For an introduction to speech-act-based workflow modeling refer to Winograd, Flores (1986).

436. Refer to McCoy (2000).

processes is the least time consuming step in a workflow project, compared to the time needed for technical integration. Thus, the economic benefit provided by a generic workflow model representation is limited. Nevertheless, on an educational level the WfMC Interface 1 specification provides a good overview about the common elements of a workflow model and their relationships.

WfMC Interface 2 & 3

The WfMC Interfaces 2 and 3 form the WAPI specification core. *Interface 2* specifies the communication between a workflow engine and client applications that are used by workflow participants to interact with the workflow management system. This concerns mainly the presentation of the work list, the selection of work-items, and the notification for overdue items. *Interface 3* specifies the API functions for the integration of invoked applications. This relates mainly to the passing of data between the workflow engine and a remote application, and handling application return codes.

While Interface 2 has a *"pull"* character, i. e., a workflow participant actively selects a work-item for further processing, thus "pulling" the work from the workflow engine, Interface 3 implements a *"push"* model, i. e., an application is invoked by the workflow engine and returns control after it has finished processing. The close relationship between the two interfaces ultimately led to a merged specification, which defines a standard set of API functions a workflow engine should support, the so-called Workflow Application Programming Interface (WAPI).[438] This abstract specification defines on one side the operations a workflow management system performs on an outside system, on the other side the operations that external systems can invoke on a workflow engine. These operations include the instantiation, starting, manipulation, and stopping of workflow instances. The current specification contains - besides the abstract description - a reference implementation in C. It is in a stable state and has been implemented by a number of vendors.[439] Still, most workflow users rely on vendor specific API implementations, since these offer more functionality and are often offered as Java classes or component objects (COM, CORBA-IDL), which offer a better fit for the surrounding system architecture.

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437. Compare WfMC (XPDL) (2002). An Open Source workflow engines that includes XPDL support is Enhydra Shark (http://shark.objectweb.org); an Open Source graphical workflow editor that exports XPDL is JaWE (http://jawe.enhydra.org).

438. Compare WfMC (WAPI) (1998).

439. For example Concentus KI Shell, IBM FlowMark/MQSeries Workflow, Hitachi Work Coordinator, SAP Business Workflow. Note that these conformance statements come directly from the vendors and have not been validated by an independent certification authority (http://www.wfmc.org).

WfMC Interface 4 and Wf-XML

The WfMC Interface 4 specifies the communication across different workflow engines in the sense of a process-to-process interaction. The first version of this interface was published in 1996,[440] the current version 2.0 has been published in 1999.[441] The specification of Interface 4 consists of an abstract description of interoperability functions (e. g., instantiating a workflow, starting, stopping, aborting a workflow instance, etc.), as well as different bindings to messaging protocols and transport mechanisms. The first published binding relied on MIME, which enabled workflow management systems to interoperate through the exchange of e-mail messages.[442] Operational implementations of this binding were presented in the course of an interoperability challenge by three workflow vendors (DST, FileNet, and Staffware) in March 1999. Despite the availability of a stable specification, most workflow vendors are reluctant to implement the Interface 4 standard. This reluctance can be explained by the following observations:

- There is no pressure from the workflow user community to implement interoperability features yet. Many enterprises are still experimenting with workflow implementations, rather than employing operative system.[443] Only the increasing use of embedded workflow systems, permeating the system infrastructure of enterprises, will create the necessity to couple different workflow management systems within one enterprise along a common process model.
- E-Mail as a transport medium is not the optimal choice for workflow interoperability, since quality-of-service standards as well as the acknowledgement of messages are difficult to realize across different e-mail platforms.

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440. Compare WfMC (IF4 1.0) (1996).
441. Compare WfMC (IF4 2.0) (1999).
442. Compare WfMC (MIME) (2000).
443. Compare for example the survey by Chroust, Bergsmann (1995). Out of 8000 questionnaires, 227 responded to the survey, and 70 of those responding were using workflow. In a similar study, KUENG stated that on January 1st, 1998, in Switzerland about 1% of small enterprises (2-99 employees) used workflow technology, 6% of medium-sized enterprises (100-499 employees) and 12% of large enterprises (500 or more employees). Compare Kueng (1998); Kueng (2000). In Kueng (1997) the author points out that the interest in workflow technology is a lot bigger than the number of actual projects.

    The author of this book conducted a survey among German public utility companies in the spring of 1998. Out of 128 questionnaires, 80 were returned. Out of these 80 companies, 14% had no plans to use workflow in the foreseeable future, 12% were conducting pilot projects, 8% were using productive systems, 4% stated, their system implementation had failed, 26% were planning to begin a project within 12 months, while 36% were planning a project within the next 36 months. For further results of this study, refer to zur Muehlen (EVU) (2002), pp. 520-526.

In the context of the Wf-XML standardization (described below), a new binding for Interface 4 messages was presented. Within Wf-XML, the interoperability messages are encoded using XML, and exchanged using the web-specific Hypertext Transfer Protocol (HTTP). This version of Interface 4 will serve as the basis for further interoperability standards, while existing Interface 4/MIME standards are mostly theoretical concepts without matching implementations.

The WfMC provides standards which define only the basic operations for a cross-enterprise or cross-system workflow implementation. For the definition of context data (i. e., business data that is exchanged during a B2B process) as well as other relevant parameters (e. g., legal frameworks, quality of service parameters, security mechanisms, etc.), the specification of so-called interoperability contracts is recommended.[444] Due to this fact, the WfMC Interface 4 specification is mostly free of overlaps with existing or future B2B standards. For example, the interoperability contract for a Wf-XML implementation could be specified using IBM's Trading Partner Agreement Markup Language (tpaML)[445], while context data may be described using domain-specific formats.

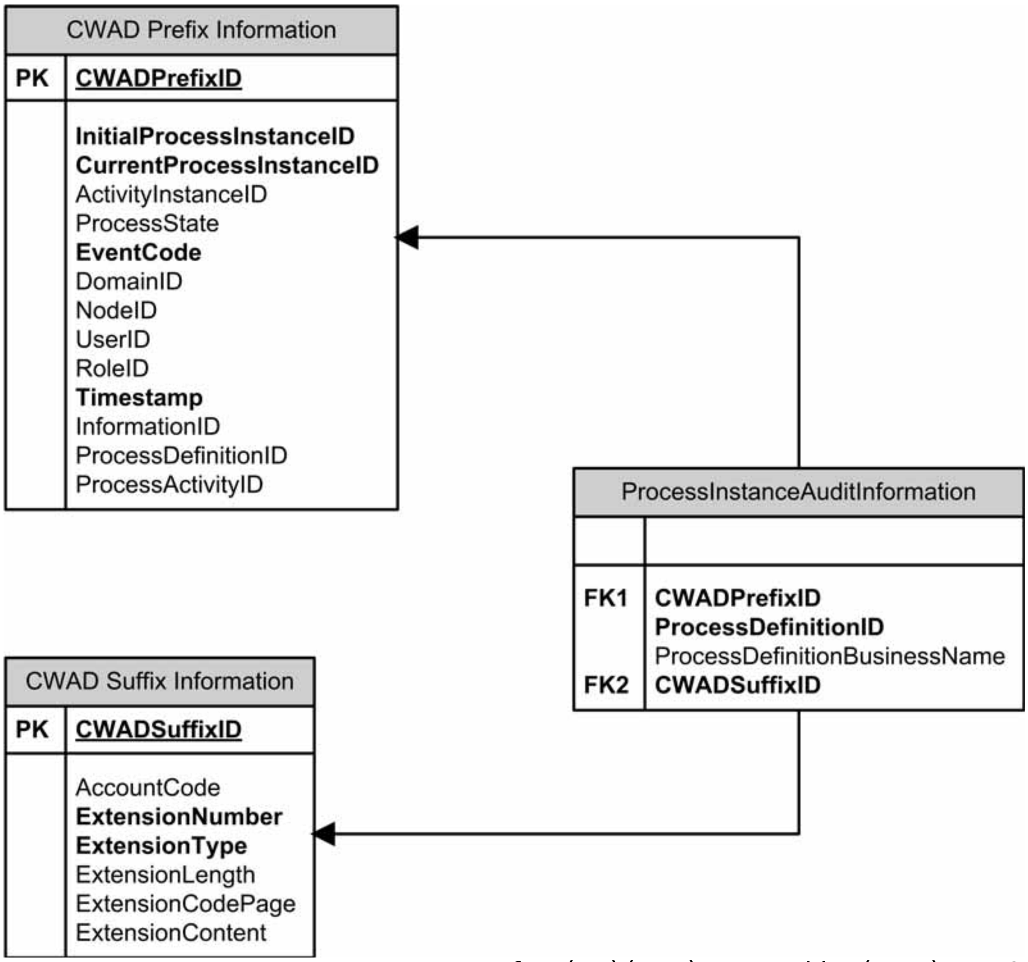
WfMC Interface 5

Interface 5 describes the format of the run time protocol produced by a workflow enactment service, the so-called audit trail.[446] The current version 2.0 describes the data format of log entries as well as the state changes responsible for creating these log entries. Figure 3-7 shows the data structure of an audit trail entry that describes the creation of a process instance. The data structure consists of a header, which is identical for every event type recorded, and a body, which is different for each event type.

This data structure can be enhanced by workflow vendors to accommodate proprietary attributes. Interface 5, despite having received considerably less attention than the other four WfMC interfaces, could be of interest for users of different workflow engines, since the standardized audit trail format makes it easier to integrate the output of different workflow management systems into a consistent process controlling database. We present such an approach in chapter 4.

On the one hand, timestamps and other attributes recorded in the audit trail could help improve the quality of cost accounting methods such as

444. Compare WfMC (IF4) (1999).
445. Compare the tpaML specification at http://www-106.ibm.com/developerworks/library/tpaml.html [Download 2002-06-02]
446. Compare WfMC (IF 5) (1999).



Source: WfMC (IF 5) (1999); zur Muehlen (2000), p. 556.

Figure 3-7: WfMC Interface 5 Data Structure

activity-based costing.[447] On the other hand, the provision of recorded workflow information in front-end applications, such as Customer Relationship Management systems (CRM) or call-center-applications can improve the tracking of customer behavior and customer histories. Furthermore, the use of data mining approaches on audit trail information may help discover potential weaknesses of the underlying workflow models, which could be corrected through reorganization measures.[448]

The most significant specifications of the WfMC so far, are the glossary, the reference model, and different versions of Interface 4. Especially the Wf-XML version of Interface 4 shows some promising aspects, even though competing standards like BPML[449], BPEL4WS[450] (a merger of WSFL[451]

[447] For a discussion of the integration of workflow audit trail data into an activity-based costing system compare Weiß, Zerbe (1995); Weiß (1998); Weiß (1999).

[448] The reconstruction of workflow models from audit trail information has been proposed by Agrawal, Gunopulos, Leymann (1998) and submitted for a patent by Agrawal, Leymann, Roller (1998).

[449] Compare Arkin (2002).

[450] Compare Curbera et al. (2002).

and XLANG[452]), and WS-CDL[453] are covering aspects of Wf-XML functionality, and are based on XML and the HTTP protocol as well.[454] From the perspective of data warehouse and controlling users, a stronger emphasis on Interface 5 would be desirable. How this demand will be addressed is still unclear, since the WfMC - like many other standardization groups - is a volunteer organization and only has a limited set of resources to work with. As the only true workflow-oriented standardization organization, the work of the WfMC will continue to impact the design of workflow management products in the future. Even if proposed standards are not implemented by its members, the standardization process in itself helps to increase the awareness of workflow vendors and users about the requirements workflow infrastructures have to satisfy in practice.

3.4.3 Object Management Group (OMG)

In addition to the WfMC, the Object Management Group partially addresses the workflow domain. The OMG was founded in 1989 as a group of software vendors, consultants and software users that were using (or were interested in) object-oriented technology. It is organized in three committees:

- The Platform Technology Committee (PTC) specifies basic technical standards, for example services for the distribution of objects or details of programming language specifications.
- The Domain Technology Committee (DTC) is dedicated to standards relating to specific business domains. It is organized in several working groups with domain-specific focus, for instance CORBAmed for the area of health care.
- The Architecture Board, similar to the Steering Committee of the WfMC, controls the OMG activities and coordinates the consistency and technical integrity of DTC and PTC work.

The OMG standardization process starts with the design of a request for information (RFI) by a task force. After approval from the respective technical committee, the RFI is issued and responses are fielded by the task force, to determine the interest and state-of-the-art of a particular technical field. If the task force receives a satisfactory feedback, a request for proposals (RFP) is drafted by the task force and is passed to the architectural board for

451. Compare Leymann (2001).
452. Compare Thatte (2001).
453. Compare W3C (2004).
454. For an extensive discussion of the design philosophies behind Wf-XML and the other standards mentioned above compare zur Muehlen et al. (2004).

approval. Such a request relates to ongoing standardization efforts and is used to solicit standards proposals from companies interested in the particular field. If the architecture board approves the RFP, it is issued by the technical committee responsible for the task force and proposals are collected. After an evaluation and voting phase, which can include several rounds of supplements and improvements, one of the proposals is recommended to the architecture board and to the board of directors of the OMG. After the proposal is formally accepted by the architecture board and approved by the board of directors, a finalization task force is instantiated, which deals with suggestions and objections from OMG members. After the revision phase, the standard is issued as an official OMG specification. Those companies submitting a proposal have implicitly signaled their agreement to implement the adopted standard within a 12 month time frame.

The core of OMG standards work is the Object Management Architecture (OMA), which describes an architectural framework for the design of object-oriented application systems. This framework is built around a central distribution layer, the object request broker, which is designed according to the common object request broker architecture (CORBA). This broker provides a communication bus that provides services for the integration of distributed, object-oriented application components. The components using the broker infrastructure need not be aware of the location or technical specification of other components they communicate with. The interfaces for the communication between the broker and the components are specified using an interface definition language (IDL). Through the use of IDL, legacy systems can be wrapped as CORBA-objects and integrated into a CORBA-based environment. Some workflow management systems rely on CORBA as a mechanism to realize the distributed implementation of their components.[455]

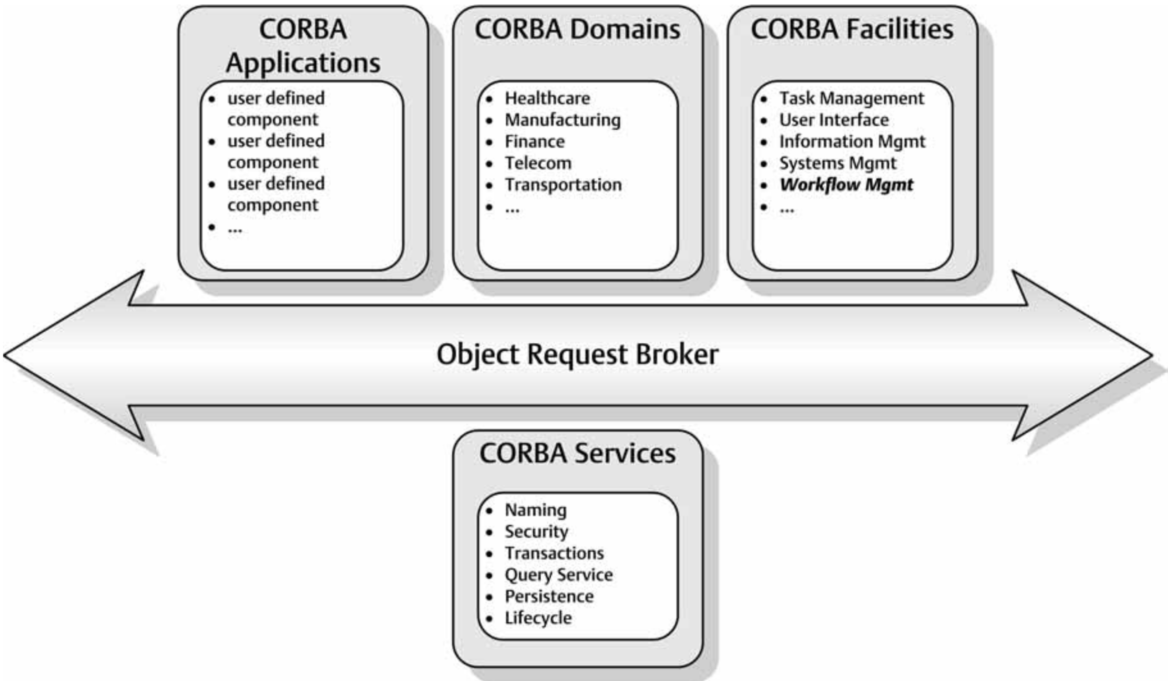
3.4.4 OMG Workflow Facility

The OMG has standardized a Workflow Facility as a part of high-level CORBA services (the so-called CORBA facilities).[456] Through an implementation of this facility, an object request broker advances from being an integration platform for workflow management systems to being a workflow-enabler and connection hub for application components. Figure 3-8

455. For example the WASA system described by Weske (CORBA) (1999).

456. Compare Object Management Group (2000); The original request for proposals was written by Schulze, Schmidt, Zenie (1997); Schulze, Bussler, Meyer-Wegener (1998) provide a discussion of expectations from the side of the OMG and a short evaluation of the initial submissions. Some authors refer to the workflow management facility using the term jointFlow. This name was the original proposal of the submitting WfMC consortium, which was finally adopted.

shows the positioning of the workflow facility among other CORBA services. Services of the workflow facility can rely on services of the business object facility. Business objects are application components that directly represent domain specific business logic.[457] They are typically designed to foster a re-use within different component-based application systems. The coordination of business objects using the workflow management facility enables application designers to create workflow-enabled business applications, without the need to implement or integrate a dedicated workflow engine.



Source: Compare Schulze, Bussler, Meyer-Wegener (1998), p. 24.

Figure 3-8: Positioning of the Workflow Facility

Structure of the OMG Workflow Facility

The workflow management facility consists of an object model, which describes the interfaces of a workflow-enabled CORBA-object. Using this object model, workflow-enabled applications can be distributed on the basis of an object request broker and communicate using standardized interfaces. The OMG workflow facility does not provide a blueprint for the internal architecture of a workflow management system. Instead, it provides an object interface for workflow applications, so client applications can create workflow instances, and manipulate these instances using well-defined interface methods. This must not be confused with the internal organization of a workflow management system - many commercial workflow management

457. Refer to Schulze (2000), pp. 81-97.

systems have been developed using object-oriented programming languages and concepts (such as Smalltalk, C++, Java), even if they do not appear as distributed systems to an observer.[458] The use of the workflow facility can serve as a wrapper for existing applications, in order to integrate these into the workflow infrastructure of an enterprise, if the organization uses CORBA as a middleware standard. From a functional perspective, the workflow facility represents a mixture of the WfMC WAPI and the function calls of the WfMC interface 4. Historically, the OMG Workflow Facility provided some core ideas for the later development of Wf-XML and ASAP.

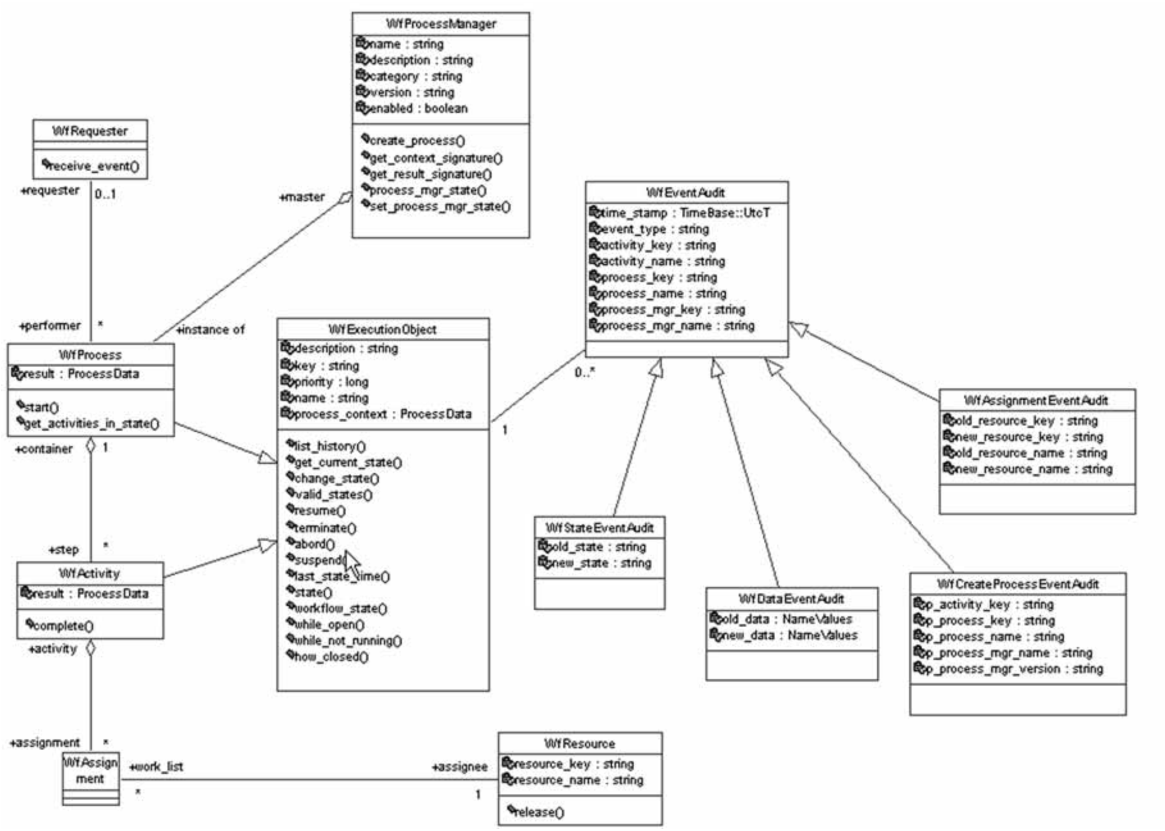
The object model of the OMG workflow facility is shown in figure 3-9 as a UML class diagram.The core object of the workflow facility is the `WfProcessManager` object, which represents a specific workflow model (or any other service that is capable of creating a workflow instances of this model). The fundamental notion of the standard is the direct communication between a requester and a workflow instance, as compared to the traditional conversation between a requester and a central workflow engine managing said workflow instance. Through the `create_process()` method, the `WfProcessManager` creates a new instance of the workflow model it manages, a `WfProcess` object. This object contains one or many objects of the type `WfActivity`, which represent the executable steps of the process. Both `WfProcess` and `WfActivity` inherit the interfaces from `WfExecutionObject`, i. e., it is possible to query both the state of an activity and the state of a workflow through the `get_current_state()` method.

Process Controlling Aspects of the Workflow Facility

For process controlling purposes, the workflow facility provides interfaces to access both the execution history of a process as well as changes in the process context, such as changes of attribute values or resource assignments.[459] The `list_history()` method provides access to the objects of the type `WfEventAudit` that are associated with a workflow or a particular activity. These `WfEventAudit` objects contain information on the source of the event and event-specific data. This information is made persistent, independent of the life-cycle of the related workflow instance or its activities. However, access to this audit data store still requires the original associated object. For this reason, an export of audit information to a persistent storage medium is necessary to preserve this information for later evalua-

458. For example, a part of the IBM FlowMark system was implemented in Smalltalk, while the Carnot process engine is implemented in Java. Compare Leymann, Altenhuber (1994); Carnot AG (2002).

459. Compare Object Management Group (Workflow) (2000), pp. 2-38 - 2-47.



Source: Object Management Group (Workflow) (2000), p. 2-3.

Figure 3-9: Workflow Facility Object Model

tions, before obsolete workflow objects are purged from a system (e. g., for performance reasons).

Future of the OMG Workflow Facility

The original request for proposals regarding the workflow management facility was issued in the summer of 1997 and led to the submission of three proposals (Nortel, EDS, and a consortium of WfMC members). After a analysis and revision phase of more than a year, the jointFlow proposal by the WfMC consortium was accepted in August 1998 and a revision task force worked on the proposal until late 1999.[460] The finalization of the specification implied that at least one of the submitting companies should have implemented the OMG workflow management facility by now. However, this is not the case, for the following reasons:

- Certain operational aspects are not specified in detail, which are necessary for the execution of workflow implemented using the object model. One example for this is the relationship between `WfActivities` and `WfResources`, which is unspecified at the moment. In

460. The final standard has been revised to version 1.2 in 2000, compare Object Management Group (2000).

order to overcome this limitation, the OMG has issued a RFP for a resource assignment interface, which received three submissions.[461]

- Domain-specific working groups of the OMG show an increasing interest in workflow. For example, the publications of the product data management enablers working group as well as documents from the CORBAmed domain task force contain concepts that are related to workflow (e. g., resource management). However, a coordinated effort is missing that could integrate these disparate approaches into a homogeneous framework. As long as such a framework is missing, vendors are better off using proprietary, but functional technologies, instead of waiting for a unified standard.
- Within the OMG opinions differ on what constitutes a workflow and how it should be modeled. Traditionally a large share of the OMG membership favors UML, which is used for the technical specification of object-oriented systems. One critical issue with the current UML diagramming types is the lack of expressions for the relationship between activities and resources. As a result, the organizational responsibilities for workflow processes cannot be expressed sufficiently. There have been isolated attempts at the enhancement of UML diagram types for workflow modeling, but a consolidated effort to enhance the UML meta model for workflow purposes has not taken place.[462]
- There is no apparent customer demand to realize workflow interoperability on the basis of the OMG model. While distributed and inter-organizational workflow management systems have been addressed by the research community since the mid-1990s,[463] the corporate practice still relies on pragmatic (and mostly proprietary) solutions. Only the increasing use of Internet standards for business transactions will ultimately lead to the development of interoperability requirements among workflow users (e. g., through the use of B2B domain standards such as RosettaNet). As a result of this development, vendors of integration platforms have begun to integrate workflow components into their products and/or acquired workflow vendors to enhance their product offerings.[464]

461. Compare IBM (2000).

462. Compare Hruby (1998); Wiegert (1998); Bastos, Bubugras, Ruiz (2002).

463. Compare Schuster (1997), who discusses architectural aspects of distributed workflow management systems. Riempp (1998) presents concepts for wide-area workflow implementations using a groupware platform. The Exotica/FMQM project of IBM was aimed at the distribution of the IBM FlowMark product. Results of the prototype found their way into the IBM MQSeries Workflow system. Compare Alonso et al. (1995); Alonso, Reinwald, Mohan (1997).

3.4.5 Workflow Management and Web Services Choreography

The standardization of lower level protocols that cover the encoding, routing, and transport of data over the TCP/IP protocol (e. g., XML, SOAP, HTTP, and WSDL) has given rise to a fast growing area of application integration under the label web services. In the widest sense, web services deal with the standardized linking of applications through the exchange of XML messages over the HTTP protocol. The increasing commercial interest in web services has led to a shift in the activities of standardization organizations. While during the 1990s intra-company processes were at the center of attention, these standards are currently being enhanced or replaced by specifications of inter-organizational message exchange and related protocols.[465] The resulting standards are partially competing and partially overlapping. Of particular interest are standards that address the interaction between (potentially long-running) processes, also known as Web Services Choreography. Web Services Choreography aims at the coordination of long-running interactions between distributed parties, which use web services to expose their externally accessible operations. The coordination of long-running interactions is necessary in almost any cross-organizational interaction, in areas ranging from electronic publishing to supply chain management.

Figure 3-10 shows the current areas of activity in standardization groups focused on inter-organizational process management. Two parties wishing to engage in inter-organizational process integration have internal operations in form of private processes (A, B, and E), which are not exposed to outside trading partners. As a façade, public processes (C and D) are created, and their activities (C1 through C3 and D1 through D3) serve as contact points for the other party. In order to automate this interaction, the two parties need to agree on a number of standards. First of all, they need to specify the semantics of the public process operations, and whether these operations receive or send data to the other party. Furthermore, the structure and content of the messages that are to be exchanged need to be defined, for example using an industry-specific format. In addition, the sequence of messages needs to be defined, including ways to detect messages that are lost or out of sync. Finally, the partners need to agree on access, addressing and authentication mechanisms that allow one party to send a message through the network gateway of the opposite party. A taxonomy of standards related to process modeling and web services is shown in figure 3-11.[466]

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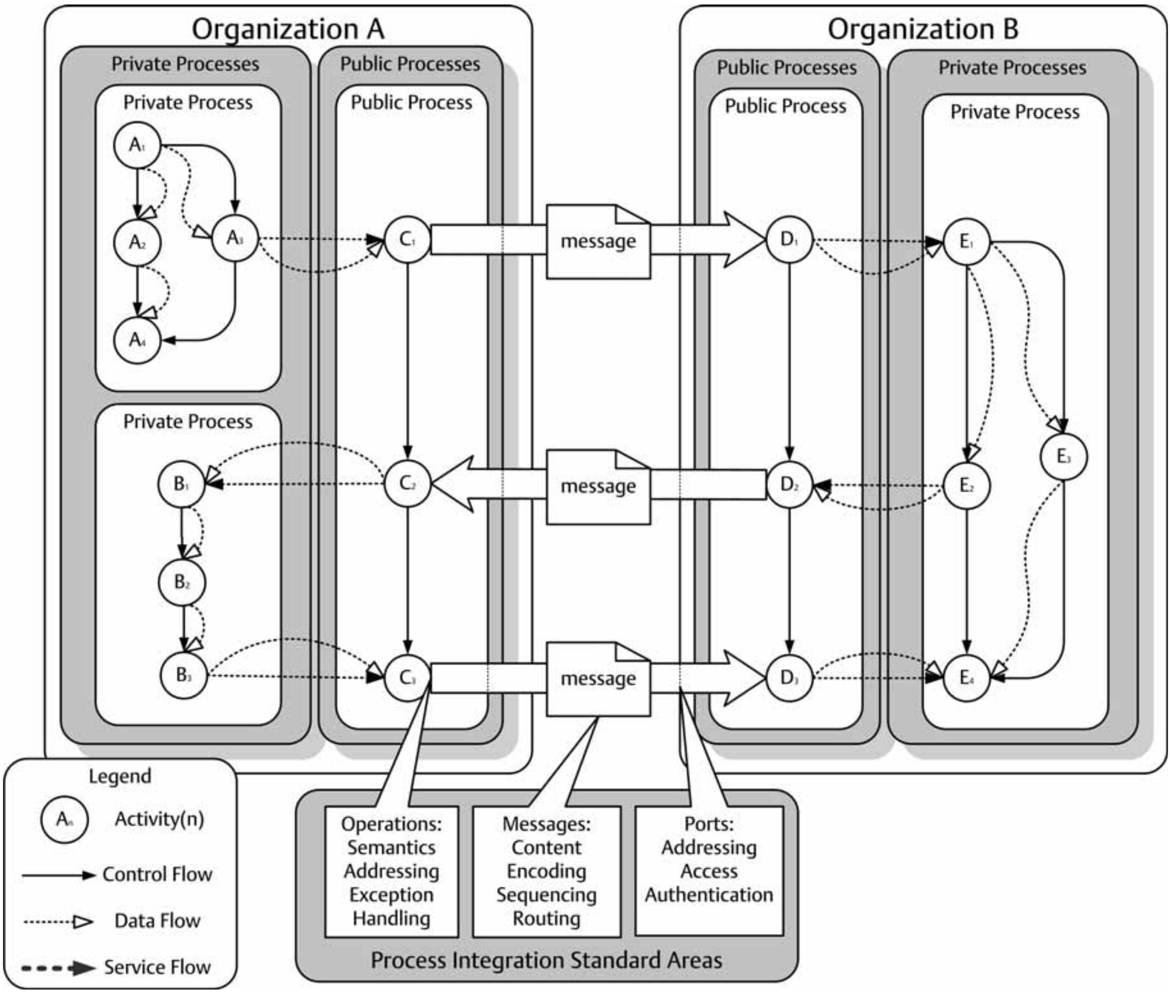
464. Compare Bussler (2002).

465. For an overview of the growing number of XML-related standardization organizations compare Kotok (2002a) and Kotok (2002b).



Source: zur Muehlen, Nickerson, Swenson (2004).

Figure 3-10: Standardization Areas in Business Process Integration

Process modeling languages like XPDL and BPEL aim at the definition of enterprise-specific business processes.[467] The companies implementing these processes exercise control over most of the resources involved in the execution of these processes, such as workflow participants or application systems. The technical implementation of these processes is based on process-aware information systems such as contemporary ERP packages or workflow management systems. The interfaces between these systems, the internal processes of a company, and outside transaction partners are specified in form of web services, whose sequence of invocation is governed by public processes.

466. For a related taxonomy compare Aissi, Malu, Srinivasan (2002), p. 55. The overview in figure 3-11 was created in collaborative meetings with members of the Workflow Management Coalition and the Business Process Management Initiative, most notably Mike Gilger and David Hollingsworth.

467. Another example for process modeling languages in the workflow domain is the Business Process Modeling Language, defined by BPMI.org (http://www.bpmi.org).

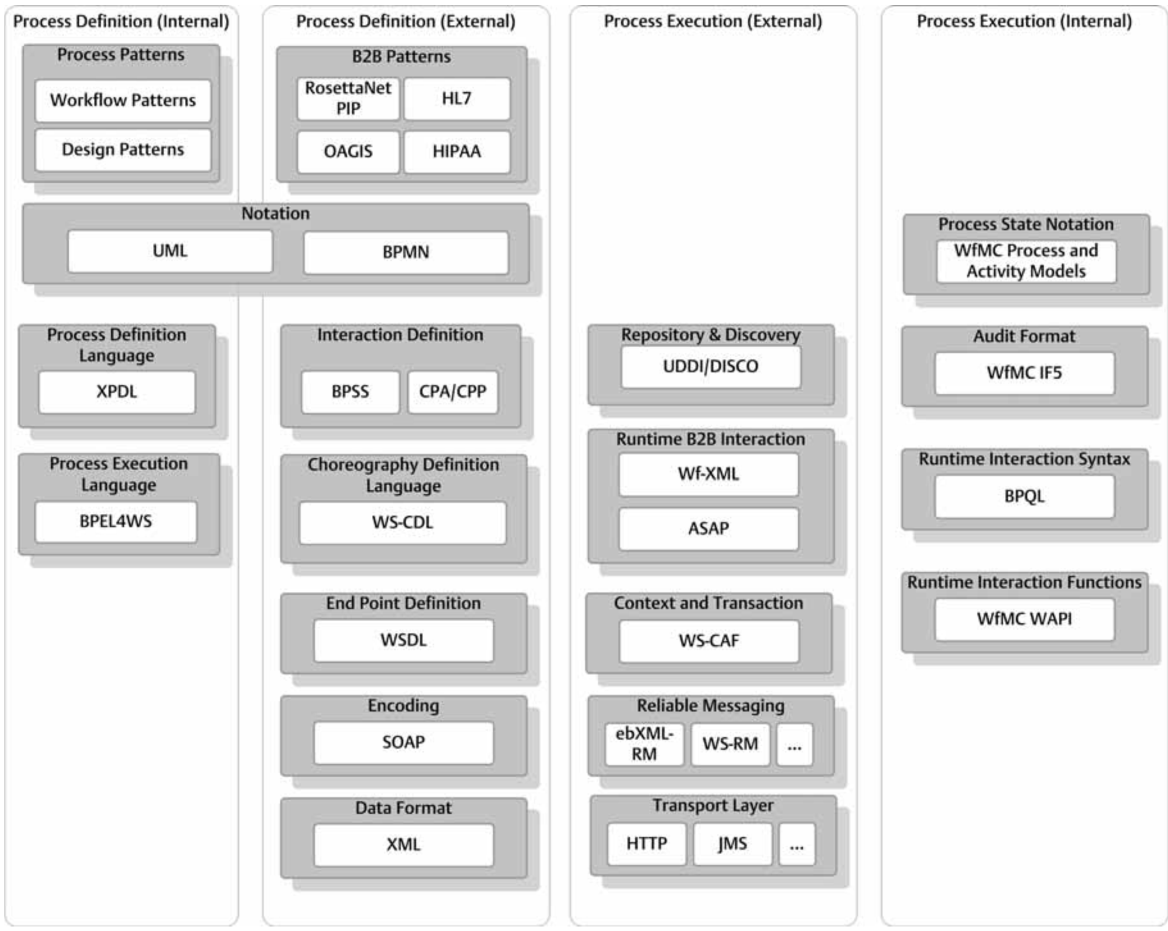


Figure 3-11: Taxonomy of Web Services Choreography Related Standards

WSDL is an XML format for the standardized specification of web services in the form of access *ports* and related access protocols (*bindings*).[468] The basic building block of WSDL is a *message*, which consists of typed elements such as documents and/or context data. Messages form *operations*, which consist either of single messages or a request/response message pair. The resulting four interaction patterns are presented in figure 3-12. Unidirectional messages are either used by a requester to *request* an action from a provider, or by a provider to *notify* a requester. Bidirectional messages either form a *request/response* pair, where a requester asks a provider to perform an action and the provider answers the request, or they form a *solicit/response* pair, where the provider asks the requester for information, which is supplied subsequently.

Multiple operations can be grouped to form a port type. A port type represents an abstract collection of semantically coherent operations (e. g., all operations related to goods receipt processes). Only in conjunction with a binding, the explicit implementation of a port type is determined. A binding

468. Compare Christensen et al. (2001).

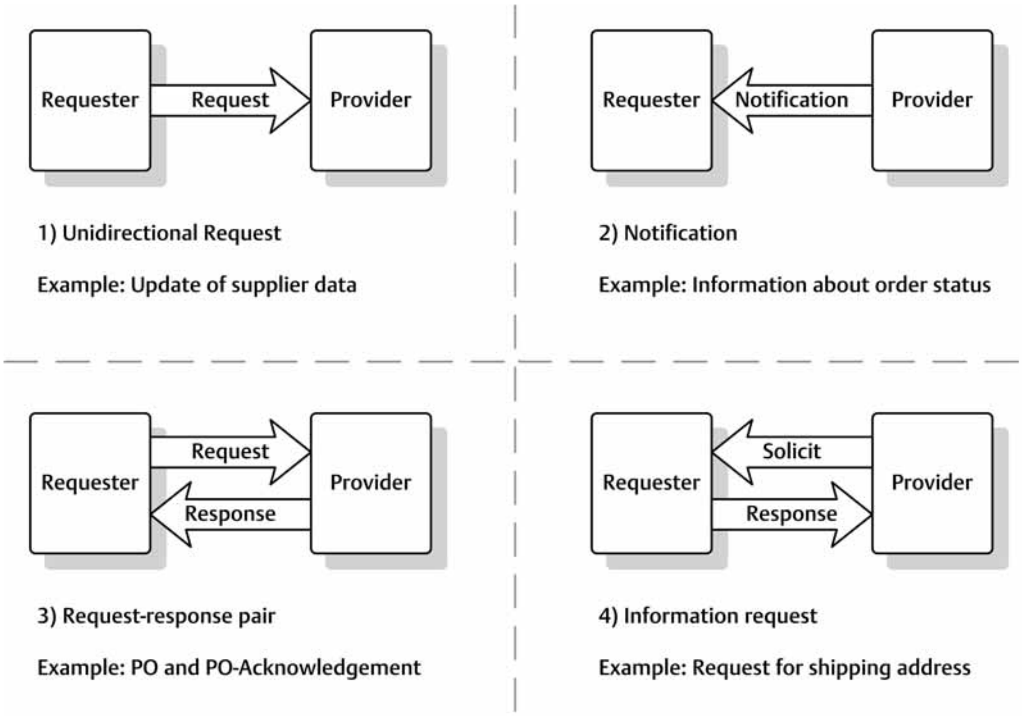


Figure 3-12: Interaction Types

specifies the data format of messages as well as the transport protocol for the message exchange. A *port* is a specific implementation of a port type using a specific binding. In principle the same port type can be implemented multiple times. This may be desirable to support the same functionality using different access mechanisms (web versus e-mail), or to provide scalability through redundant ports. The top-level element of WPDL is a *service*, which consists of one or more ports. Figure 3-13 shows the WPDL meta model as an entity-relationship diagram.

Web services can be published in directories, which rely on a standardized description format, such as Universal Description, Discovery and Integration (UDDI).[469] XML-based formats such as the Trading Partner Markup Language (tpaML) provide mechanisms to describe the non-technical aspects of an inter-organizational process, and within the eb-XML standard the specifications Collaboration Partner Protocol/Agreement (CPP and CPA) cover these aspects as well. The content of the messages, which are exchanged between business partners, can be defined using format standards, which are either generic, such as Biztalk or ebXML, or domain-specific, such as RosettaNet, SWIFT, or HL7.

469. Compare Ariba, IBM, Microsoft (2000).

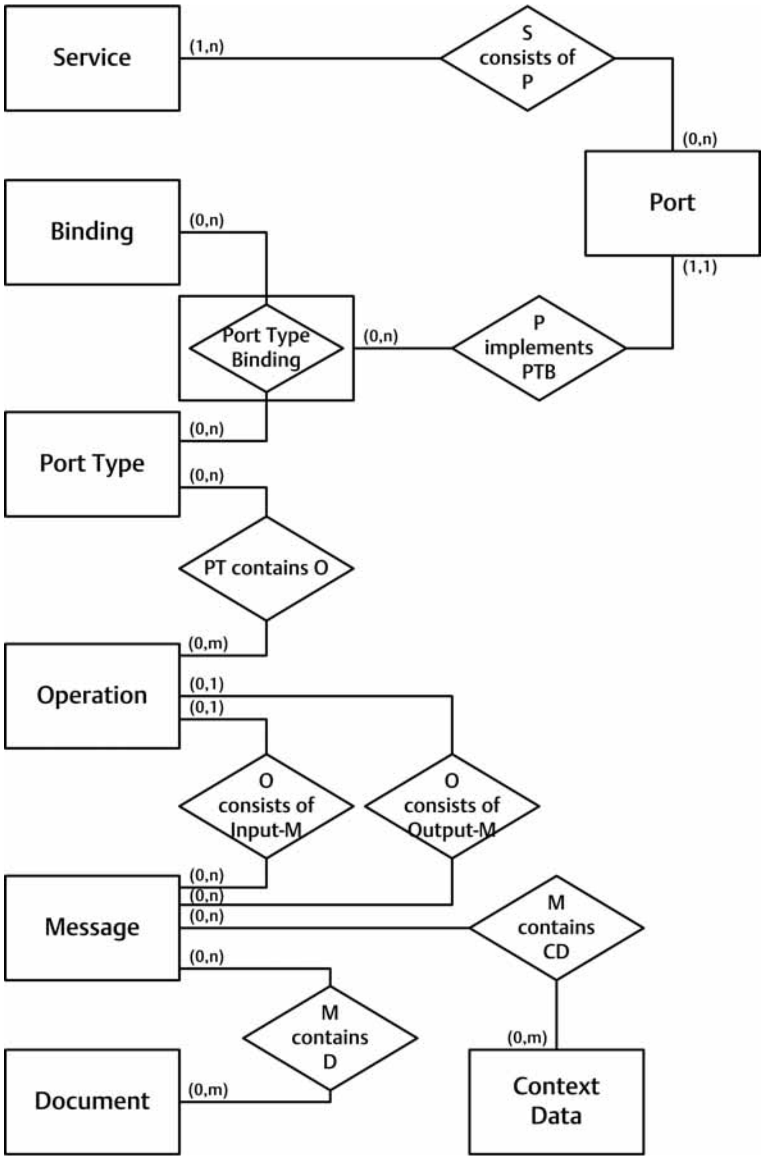


Figure 3-13: WSDL Meta Model

Figure 3-11 also includes the protocol stack for web service applications. The foundation of the protocol stack are the three standards HTTP, SOAP and WSDL. While HTTP serves as the transport protocol, messages, which are exchanged between web services, are encoded in a SOAP envelope, and sent between ports that are defined using WSDL. Using these three standards, it is possible to create web service applications that send point-to-point messages. In order to enable more complex interactions (e. g., to define the sequence of messages within a business context), an additional protocol layer is required, the web services choreography layer. WSDL only describes the functionality of web services, but not their behavior in the context of a long running business process. This behavior is represented using modeling languages for inter-organizational processes, such as the public processes of BPEL4WS or the Choreography Definition Language of the W3C (WS-CDL).

The structure of processes modeled in either private or public process specifications can be driven by the use of reference models, or reference patterns. For workflow management systems, VAN DER AALST ET AL. have defined 23 design patterns that cover the most common control flow scenarios.[470] For UML activity diagrams, another process modeling method, some general design patterns can be applied. In the public process space, domain-specific standards provide interaction patterns such as the RosettaNet Partner Interface Processes.[471]

In the following section we characterize Wf-XML as one of the standards proposed for the cross-organizational integration of business processes, since it allows for the remote observation of processes - a feature that is of interest for process monitoring and controlling applications.

3.4.6 Resource-oriented Process Choreography: Wf-XML and ASAP

Wf-XML provides a mixture between a process model and a service description in form of a process-oriented interaction protocol. It serves as a standard format for the interaction with stateful, complex services, such as workflows. The Wf-XML protocol was published by the WfMC and is influenced by the WfMC Interface 4, the OMG Workflow Facility, and the Simple Workflow Access Protocol.[472] A generic version of Wf-XML for the coordination of long-running services has been proposed in form of the Asynchronous Service Access Protocol (ASAP).[473]

History of Wf-XML and ASAP

In early 1997 a number of WfMC members felt that a lightweight alternative to the existing Interoperability specification (WfMC Interface 4) was needed and began developing an alternative protocol, which was called the Simple Workflow Access Protocol (SWAP).[474] The basic idea behind SWAP was the use of standard Internet protocols for workflow interoperability. A workflow model would be identified by a Uniform Resource Identifier (URI) and could be manipulated using a number of commands based on HTTP extensions (`LISTINSTANCES`, `CREATEPROCESSINSTANCE` etc.). An initial draft was completed early 1998, and the authors submitted it to the

470. Compare van der Aalst et al. (2003).
471. Compare RosettaNet (2002).
472. Compare Hayes et al. (2000); WfMC (Wf-XML) (2001).
473. Compare Ricker et al. (2003).
474. Compare Swenson (1998).

Internet Engineering Task Force (IETF), which was the desired standards body for this endeavor. By the end of 1998, after two birds-of-a-feather meetings[475], it became clear that the IETF was not going to adopt the SWAP specification, and members of the SWAP working group returned to the WfMC, where the ideas of the SWAP proposal were enhanced with the experiences of the OMG Workflow Facility submitters. In addition, the proprietary extensions of the HTTP protocol were removed and replaced with standard HTTP POST commands.[476] The result was the Wf-XML specification, which was published in 2000 and revised in 2001.[477] In 2003 the desire grew to extend the protocol beyond the workflow arena and apply it to long running transactions in general. Due to the different intention, a working group was founded within the OASIS standards body to work on an extended specification titled Asynchronous Service Access Protocol (ASAP). This effort is synchronized with work on a revision of the Wf-XML protocol.

Wf-XML Structure

The core for Wf-XML is a set of messages that describes the interaction between the *provider* of a process-oriented service, and a *requester* of this service. From a conceptual perspective, the hierarchical decomposition of a process can be perceived as a sequence of requester-provider message exchanges. The actions of the provider are hidden from the requester in the sense that the requester does not need to know details about the service provisioning process. Figure 3-14 illustrates this concept using a top-level process (P1) with a three-step sub-process (A1, A2, A3). Sub-process A3 is implemented through two additional activities B1 and B2.

The interaction between requester and provider is realized through a set of messages that are exchanged. During the first step of the interaction a requester sends a `CreateProcessInstance` command to a process manager (which represents the workflow model). The process manager creates a process instance and passes the address of this process instance back to an observer, who will interact with the process instance. Requester and observer can, but need not be the same entity. Subsequently the observer communicates with the process instance (performer), but no longer with the process manager. The observer can manipulate the state of the process instance through the `ChangeProcessInstanceState` command, i. e.,

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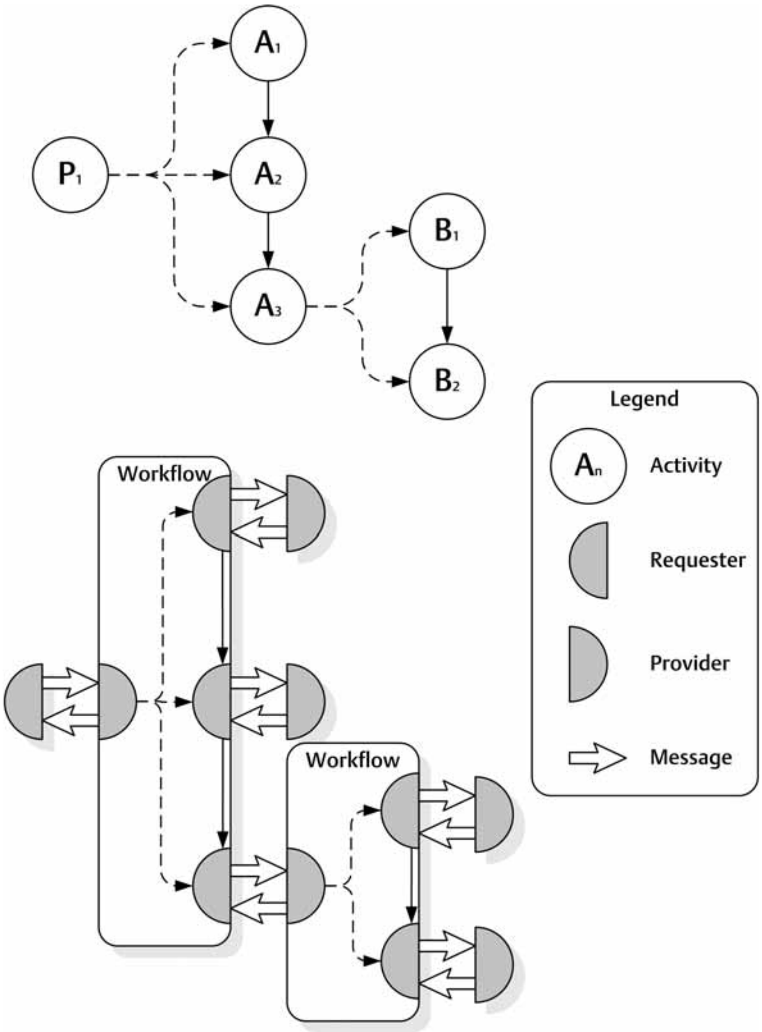
475. Compare Khare (1998).
476. Compare Swenson (2000).
477. Compare WfMC (Wf-XML) (2001). Interestingly the original effort was started outside of the WfMC, because the consortium members were dissatisfied with the length of time it took to specify and publish standards within the WfMC.



Source: Compare Swenson, zur Muehlen (2001).

Figure 3-14: Nested Workflow Interaction

he can start, suspend, resume, and abort the process instance through this command. The process instance will notify the observer of state changes (such as the completion of the process instance). Through the `GetProcessInstanceData` command the observer can request elements from an agreed-upon data structure (e. g., the shipping date of an order). Figure 3-15 shows the basic interaction pattern between requester and provider.

The overall interaction between requester and provider is oriented along the web architecture principles that have been documented by Fielding as Representational State Transfer (REST).[478] A monitoring agent could register itself to a process instance as an observer and record events about the execution of this process instance. The application of monitoring principles to processes that are executed at different locations has been documented in the AFRICA project.[479] This project implemented a distributed help desk

478. Compare Fielding (2000).

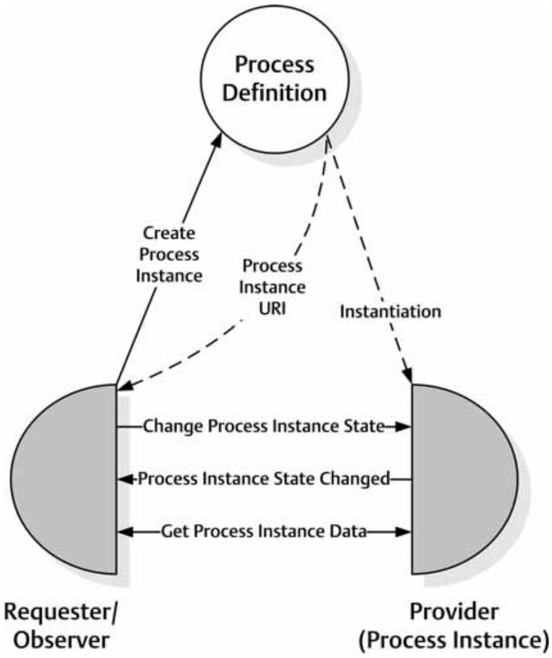


Figure 3-15: Wf-XML Message Types

process using three different process management systems. Monitoring information about the current state of the process was collected and visualized through a central process observer, using Wf-XML concepts.

The monitoring and controlling of business processes can deliver especially useful information, if the underlying structure of the business processes is available for reference. Several standard modeling languages for business processes in the workflow context have been indicated in figure 3-11. We will discuss the properties of these languages in section 3.5.3.

3.5 Development of Workflow Applications

In the previous section we have discussed major standardization efforts in the field of workflow management. In this section we focus on the actual development of workflow applications, i.e., the design and deployment of process-aware information systems that are based in whole or in part on workflow technology.

3.5.1 Procedure Models for Workflow Application Development

The development of a workflow application is similar to the development of a traditional application system, since workflow management systems are a specific category of application systems.[480] As a result, procedure models

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479. Compare zur Muehlen, Klein (2000).
480. Compare Böhm (2000), p. 18.

for software development can be applied to the development of workflow applications, such as the waterfall model[481], the spiral model[482], or the Rational Unified Process.[483] These procedure models can be classified according to the main objective during the development phases.[484] While *functional* approaches focus on the development of algorithmic solutions, *data-oriented* approaches stress the separation of data management and application logic. *Rule-based* application development separates a rule-base from an inference engine that processes these rules. *Process-oriented* development approaches separate the application logic from the control flow, which makes them suitable for the development of workflow applications.

KWAN and BALASUBRAMANIAN have presented a high-level development process for workflow applications.[485] After a requirements analysis phase (*study phase*), the requirements definition documents are specified, and separate development phases for process logic and activity logic start.[486] The design and development phase is performed in two concurrent threads, one for the specification of the behavioral perspective, and one for the specification of the functional and operational perspectives. Next, the results are integrated, tested, and documented. Changes during the execution and evaluation phase lead back to the development and specification tasks, respectively.

ORTNER has proposed a generic multi-path procedure model for the development of application systems, which he illustrates using examples from the workflow management domain.[487] His generic approach is based on the separation of method-neutral and method-specific design phases.

WESKE ET AL. have analyzed different approaches for the design of workflow applications and identified a number of problems during the development process that they try to overcome with the specification of a reference procedure model.[488] Their reference model for workflow application design process is shown in figure 3-16. It is similar to the conventional waterfall model, using feedback loops between the different development stages.

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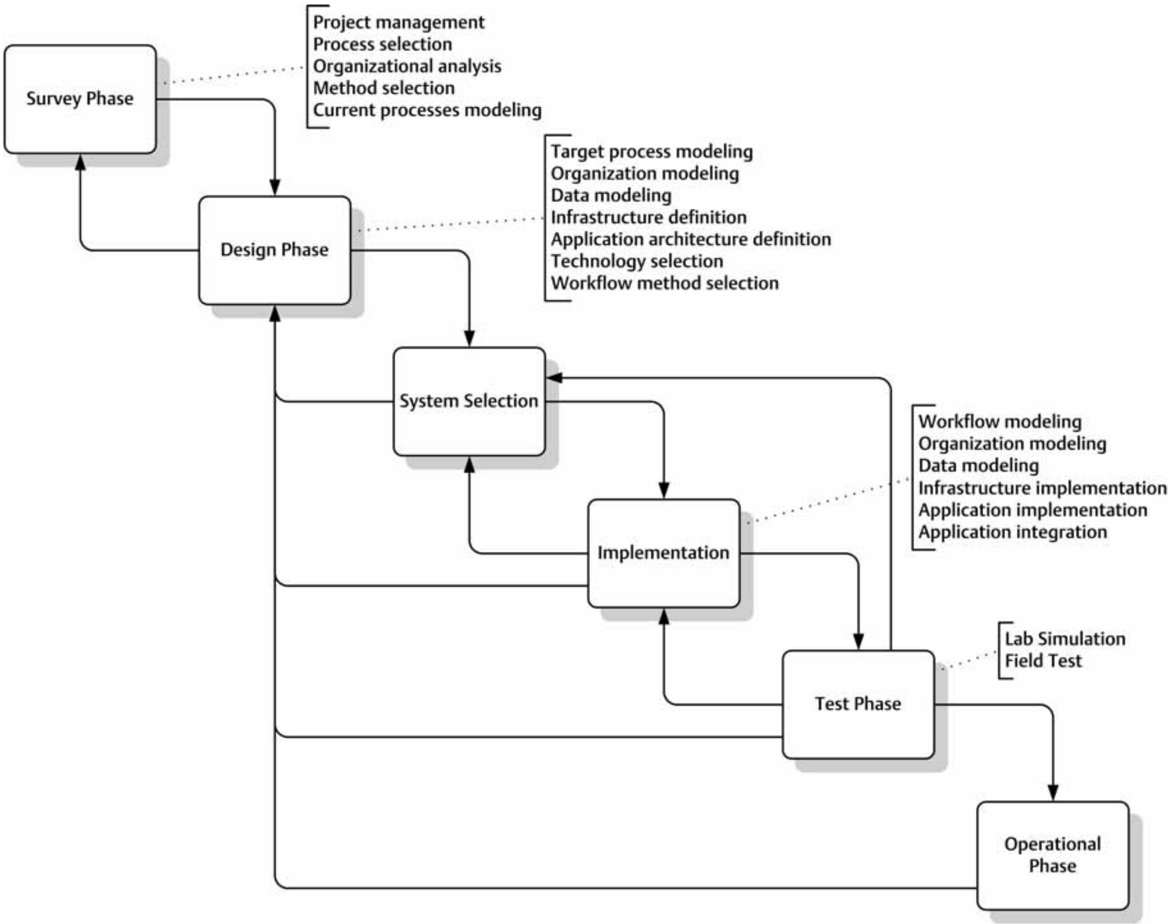
481. Compare Royce (1970).
482. Compare Boehm (1988).
483. Compare Kruchten (2001).
484. Compare Ortner (1998), pp. 329-331.
485. Refer to Kwan, Balasubramanian (1998).
486. The authors name this phase *analysis phase*, despite the specification activities. Compare Kwan, Balasubramanian (1998), p. 315.
487. Compare Ortner (1998).
488. Compare Weske et al. (2001).



Source: Compare Weske et al. (1999), p. 4.

Figure 3-16: Reference Model for the Workflow Application Design Process

The following sections describe the main tasks of the workflow application design phase, namely the specification of process models and organization models, as well as the planning of application integration.[489]

3.5.2 Process Modeling

Identification of workflow-fit Processes

Prior to any process specification, the processes which should be automated have to be selected. The identification of processes with high workflow potential, i. e., those processes that can be supported by workflow applications profitably, is an essential step in a workflow application development project. The selected processes and their system environments are core determinants of the technical and business-related requirements workflow systems have to satisfy.[490] If a workflow management system is already in place[491], capabilities of the workflow enactment service have a direct impact on the process selection. A structured framework for the selection of

489. For a detailed discussion of the other phases, refer to Weske et al. (1999).
490. Compare Bartholomew (1995).

workflow-fit business processes has been developed by BECKER ET AL.[492] This model has been field tested in a workflow project in a public utility enterprise. The framework separates fundamental workflow suitability, organizational constraints, and the economic benefits of process automation. Workflow suitability takes into account factors such as process structure, separation of tasks, and the number of organizational interfaces. Organizational constraints can impact the success of a workflow project, such as the commitment of process participants to a workflow project. The economic benefits of process automation are measured using the efficiency goals discussed in section 2.1.2 on page 30. Alternative taxonomies have been presented by KUENG[493], who focuses on the external attributes of a process, and KOBIELUS, who names six key criteria for the diagnosis of workflow suitable processes: Speed, cost, accuracy, quality, customer satisfaction and quality.[494]

Specification of Workflow Models

A variety of process modeling languages are available for the specification of workflow models. These languages differ with regard to the focal modeling construct of the process model. Activity-centered languages allow the modeling of processes as a network of tasks or activities that are ordered using producer/consumer relationships, or transitions. Languages focusing on the process object describe a process as the legal sequence of state changes of the process object. An example of this approach to process modeling are document publishing processes, where a document changes between states such as *draft, revised, accepted* and *rejected*. Languages focusing on the resources participating in the process may represent a process as a network of processing stations that interact with each other.[495]

A different classification has been proposed by CARLSEN, who distinguishes five groups of process modeling languages:[496]

491. For example, if a workflow-enabled application system is already being used by the organization.

492. Compare Becker et al. (1999); A modified version of the framework was published in zur Muehlen, v. Uthmann (2000) and Becker et al. (2000).

493. Compare Kueng (1995).

494. Refer to Kobielus (1997), pp. 20-21.

495. BARBARÁ, MEHROTRA and RUSINKIEWICZ describe a system, where an intelligent process object migrates through a network of “black box” processing stations. If the processing station is capable of performing the task required by the process object, it enacts this task. Otherwise the process object migrates to another processing node. This modeling paradigm is a mixture of the process-object-oriented and the process-participant-oriented modeling methods. Compare Barbará, Mehrotra, Rusinkiewicz (1996).

496. Compare Carlsen (1997).

- *Input-Process-Output-based languages*, such as the activity networks used in IBM MQSeries Workflow.[497] These languages describe a workflow as a directed graph of activities, denoting the sequence of their execution.
- *Speech-Act-based approaches* (sometimes called Language Action approaches) as used in Action Technologies' Action Workflow product.[498] These approaches model a workflow as an interaction between (at least) two participants that follow a structured cycle of conversation. Namely the phases negotiation, acceptance, performance and review are distinguished.
- *Constraint-based modeling methods*, such as Generalized Process Structure Grammar (GPSG).[499] These approaches describe a process as a set of constraints, leaving room for flexibility that is otherwise governed by the restrictions of the IPO- or Speech-Act-based approaches.
- *Role-modeling based process descriptions*, such as Role Activity Diagrams (RADs).
- *Systems thinking and system dynamics* are concepts that are used in conjunction with the concept of learning organizations.[500]

Process Definition Languages

Process definition languages for the specification of workflow models can be separated into languages with a graphical representation and languages with a textual representation. Graphical modeling languages are typically found in business process modeling tools. They can be used for the specification of the overall process structure and the decomposition of sub-processes and activities. Aspects covered by these languages are the functional and behavioral perspective of a workflow application. Nevertheless, graphical modeling languages often lack expressiveness for the specification of other perspectives.[501] WESKE and VOSSEN distinguish between graph-based and net-based languages as well as workflow programming languages. While graph-based and net-based languages may be either textual or graphical, workflow programming languages are typically text-based. An overview of graphical and text-based process definition languages is given in table 3-5.[502]

Generalized Process Structure Grammars

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497. Compare Leymann, Altenhuber (1994).
498. Compare Medina-Mora et al. (1992).
499. Compare Glance et al. (1996).
500. Compare Senge (1990).
501. Compare Böhm (2000), pp. 32ff.

	Textual Representation	Graphical Representation
Graph-based Languages	■ Workflow Process Definition Language (WPDL, XPDL) ■ Business Process Modeling Language (BPML) ■ Business Process Execution Language for Web Services (BPEL4WS) ■ EPC Markup Language (EPML)	■ Activity Nets ■ Business Process Modeling Notation (BPMN) ■ Control Flow Graph ■ Event-driven Process Chains
Net-based Languages	■ Petri Net Markup Language (PNML) ■ Yet Another Workflow Language (YAWL)	■ Funsoft Nets ■ Flow Nets ■ Workflow Nets
Workflow Programming Languages	■ Mobile ■ FlowMark Definition Language (FDL) ■ Transaction Datalog	■ State and Activity Charts

Table 3-5: Process Definition Languages

The approach of Generalized Process Structure Grammars (GPSG) was developed by members of the Rank Xerox Research Center in Grenoble in the mid-1990s. GPSG is intended to enable the modeling of processes without prescribing an exact execution path of activities.[503] It was inspired by the idea of Generalized Phrase Structure Grammar, which is a formal model of the syntax of natural language.[504] The fundamental objects of a GPSG are rules, feature objects, and feature constraints.[505] Activity-centered rules are used to describe the goals of activities, and how these goals can be decomposed into sub-goals, including the conditions that describe dependencies between activities. Document-centered rules describe the decomposition of documents into sub-documents. Constraints for document-centered rules describe the relationships among sub-documents, e. g., the fact that a summary in a management document precedes the body of the document. Activities and documents are described in terms of name-value pairs (features), i. e. attributes and their values, and therefore represent feature structures. Feature constraints describe interdependencies between objects.

The description of a process in GPSG is based on constraints that govern the sequence of activities within the process. Through the specification of

502. The references for the languages mentioned in the table are as follows: Activity Nets and FDL, refer to Leymann, Altenhuber (1994). BPML, refer to BPMI.org (2002). BPMN, refer to White (2002). Control Flow Graph, refer to Alonso et al. (1996). Event-driven Process Chains, refer to Keller, Nüttgens, Scheer (1992); EPML, refer to Mendling, Nüttgens (2004); Flow Nets, refer to Ellis, Keddara and Rozenberg (1995). Funsoft Nets, refer to Gruhn, Deiters (1995). Mobile, refer to Jablonski, Bussler (1996). State and Activity Charts refer to Harel (1988). Transaction Datalog, refer to Bonner (1999). PNML, refer to Jüngel, Kindler, Weber (2000). Workflow Nets, refer to van der Aalst (1998). WPDL, refer to WfMC (WPDL) (1999); XPDL, refer to WfMC (XPDL) (2002); YAWL, refer to van der Aalst, ter Hofstede (2003).

503. Compare Glance, Pagani, Pareschi (1996). Dourish et al. (1995) have implemented GPSG in their Contraflow and FreeFlow prototypes.

504. Compare Gazdar et al. (1985).

505. Compare Glance, Pagani, Pareschi (1996), p. 181.

grammatical rules that define the constraints a process has to satisfy, a multi-dimensional space of possible process execution paths is opened. GPSG-based process models can be extended or altered by adding additional or removing constraints from the process specification, much like a rule-based expert system. GLANCE ET AL. illustrate this point:

> *"[...] Using a generative grammatical approach, a given process instance can be incrementally singled out from the space of possible workflows defined by the rules as the process evolves."*[506]

A comparison of traditional workflow management concepts, based on a process definition language, and a GPSG-driven workflow system is given in table 3-6.[507]

	PDL Approach	GPSG Approach
Workflow Engine	PDL grammar ■ Parser of user-defined process models ■ Interpreter of process models ■ Lexicon: activities, dependencies among activities	GPSG grammar ■ Generator of user-defined processes ■ Constraint solver ■ Compiler of processes
Workflow Model	■ Legal phrase defined by the user respecting the PDL grammar	■ User-defined process grammar ■ Lexicon: activities, documents, dependencies defined as feature constraints
Workflow instance	■ Instantiation of workflow model	■ Legal phrase generated by the user from the process grammar
Flexibility in workflow instance	■ Conditional statements in workflow model ■ Change of the workflow model	■ New legal phrase in the process grammar ■ New phrase in the modified process grammar

Table 3-6: Comparison of PDL-driven and GPSG-driven Workflows

While a PDL-driven workflow management system relies on a hard-coded process definition language, GPSG allows the user to specify his own language, including the objects that are part of the process (indicated as *lexicon* in the table).

GPSG as an alternative modeling approach does not address implementation issues necessary for the design of a workflow management system based on a GPSG process model. Nevertheless, the unique capabilities of GPSG, such as the extensibility of process instances as well as the virtually unlimited number of control flows possible justify the analysis of this language. Furthermore, the analysis of process instances based on a GPSG specification is different from the PDL-style languages.

506. Glance, Pagani, Pareschi (1996), p. 181.
507. Modified from Glance, Pagani, Pareschi (1996), p. 183.

Because there is no predefined control flow for the entire process within GPSG, a process controlling system would have to reconstruct process models from audit trail entries without the help of a “traditional” process model.[508]

3.5.3 Standards for Workflow Modeling Languages

Nearly every commercial workflow tool relies a proprietary modeling language for the construction of workflow models, each of which offering a different number of modeling elements to the process designer. Depending on the technical implementation of the underlying workflow engine, the same process semantics may be expressed using different modeling constructs. The purpose of standard process modeling languages is the provision of generic modeling languages that facilitate the exchange of process and workflow models across applications.

Most standardization initiatives focus on the textual representation of workflow models, but do not specify, how the elements of these languages can be rendered graphically. Only recently, the Business Process Modeling Notation was presented as an attempt to provide a unified graphical process rendition that can be applied to different underlying modeling languages.[509] An overview of current standardization efforts for process modeling languages in the context of workflow management is given in table 3-7, and both table 3-8 and table 3-9.

Name	WPDL/XPDL	BPML	PSL	PIF
Origin	WfMC Standardization	BPMI.org Standardization	NIST Standardization	MIT Research
Specification	EBNF, Text, XML	XML Schema	KIF[a]	KIF
Notation	No	Yes, BPMN	No	No
Objective	Model Exchange	Modeling	Modeling	Model Exchange
Tool Support	Product	Prototype	Prototype	Prototype
Usage	Workflows	Business Processes	Business Processes	Business Processes
Source	WfMC (WPDL) (1998); WfMC (XPDL) (2002)	BPMI.org (2002)	Knutilla et al. (1998) Note: Merged with PIF	Lee et al. (1998) Note: Merged with PSL

Table 3-7: Standards for Process Modeling Languages (Part 1)

a. For an explanation of the Knowledge Interchange Format (KIF) refer to Genesereth (1998).

508. This relates to the process mining approaches mentioned earlier, compare Agrawal, Gunopulos, Leymann (1998), van der Aalst et al. (2003), and www.processmining.org for an overview of research projects on mining process models from workflow logs.

509. Compare White (2002).

Name	GSPG	UML	WSFL	XLANG
Origin	Xerox Research	OMG Standardization	IBM Vendor	Microsoft Vendor
Specification	Text	MOF, UML, Text	XML Schema	XML Schema
Notation	No	Activity Diagrams	No	XLANG Schema
Objective	Modeling	Modeling	Modeling	Modeling
Tool Support	Research Prototype	Product	see BPEL4WS	see BPEL4WS
Area	Workflows	Workflows	Web Services	Web Services
Source	Glance, Pagani, Pareschi (1996); Dourish et al. (1996)	OMG (2001); DSTC, PrismTech (2001); Kabira, Oracle, Web-Gain (2002)	Leymann (2001) Note: Merged with XLANG to BPEL4WS	Thatte (2001) Note: Merged with WSFL to BPEL4WS

Table 3-8: Standards for Process Modeling Languages (Part 2)

Name	BPEL4WS	WSCI	WSCL	BPSS
Origin	BEA, IBM, Microsoft, SAP, Siebel (OASIS)	SUN, BEA, Intalio W3C Note	HP Labs Research	ebXML (OASIS) Standardization
Specification	XML Schema	XML Schema	XML Schema	XML Schema
Notation	BPMN (planned)	No	No	No
Objective	Modeling	Modeling	Modeling	Modeling
Tool Support	Product	None	None	Product
Area	Web Services	Web Services	Web Services	Web Services
Source	IBM (2002)	W3C (2002a)	W3C (2002b)	ebXML (2002)

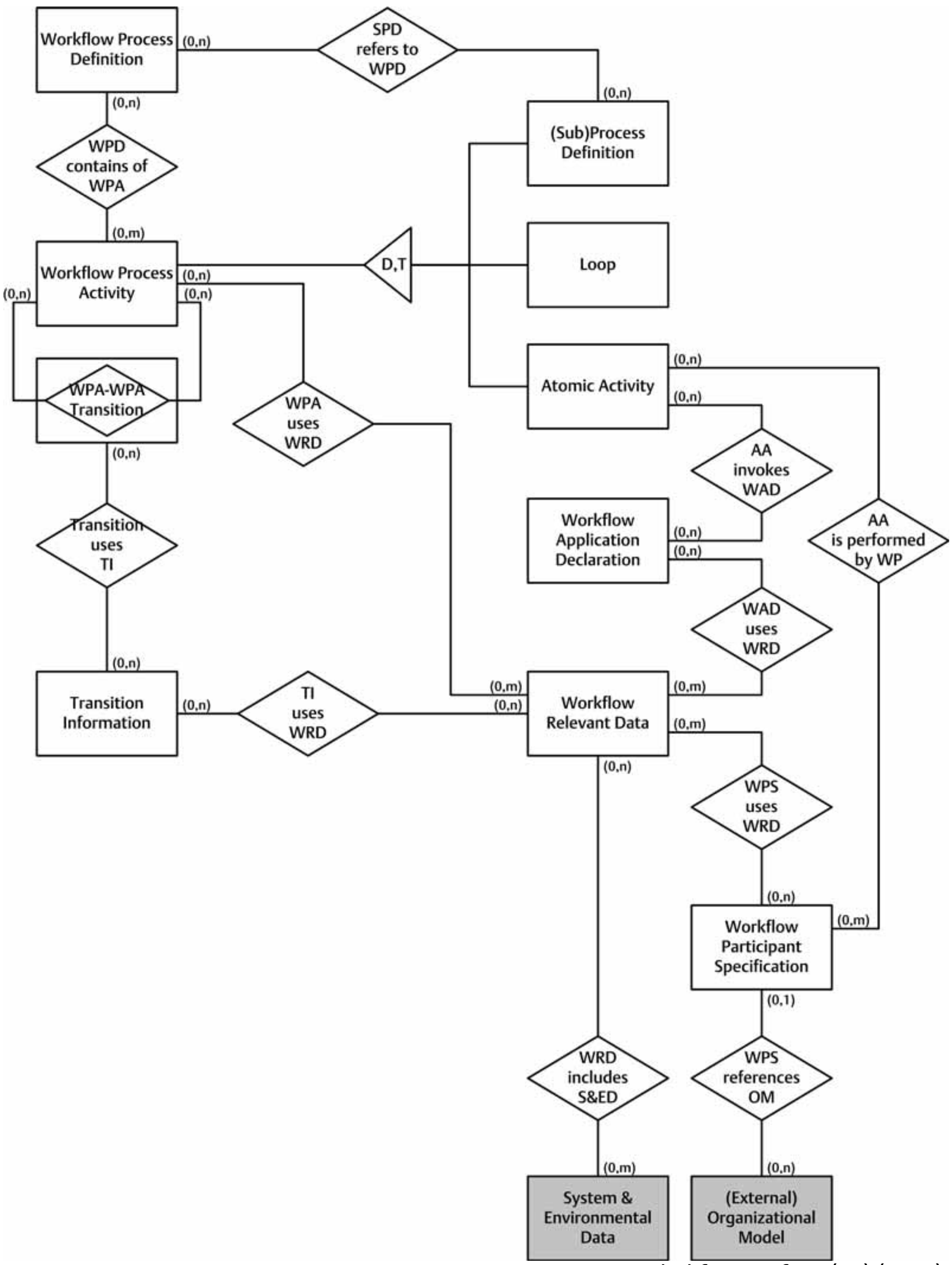
Table 3-9: Standards for Process Modeling Languages (Part 3)

WPDL and XPDL

The Workflow Process Definition Language (WPDL) is an exchange format for workflow models, and has been published as part of the WfMC Interface 1.[510] XPDL is an XML schema representation of WPDL. Workflow models can be transferred between modeling tools and workflow management systems, if these can convert their internal models to the WPDL or XPDL format.

A workflow process definition in WPDL consists of one or more workflow process activities that are linked through transitions. These transitions reflect the control flow of the process. There are no constructs to explicitly model the data flow aspect of a process. Activities within WPDL can be atomic or complex, i.e., complex activities reference sub-processes. Since

510. Compare WfMC (WPDL) (1999). For the XML rendition XPDL refer to WfMC (XPDL) (2002).

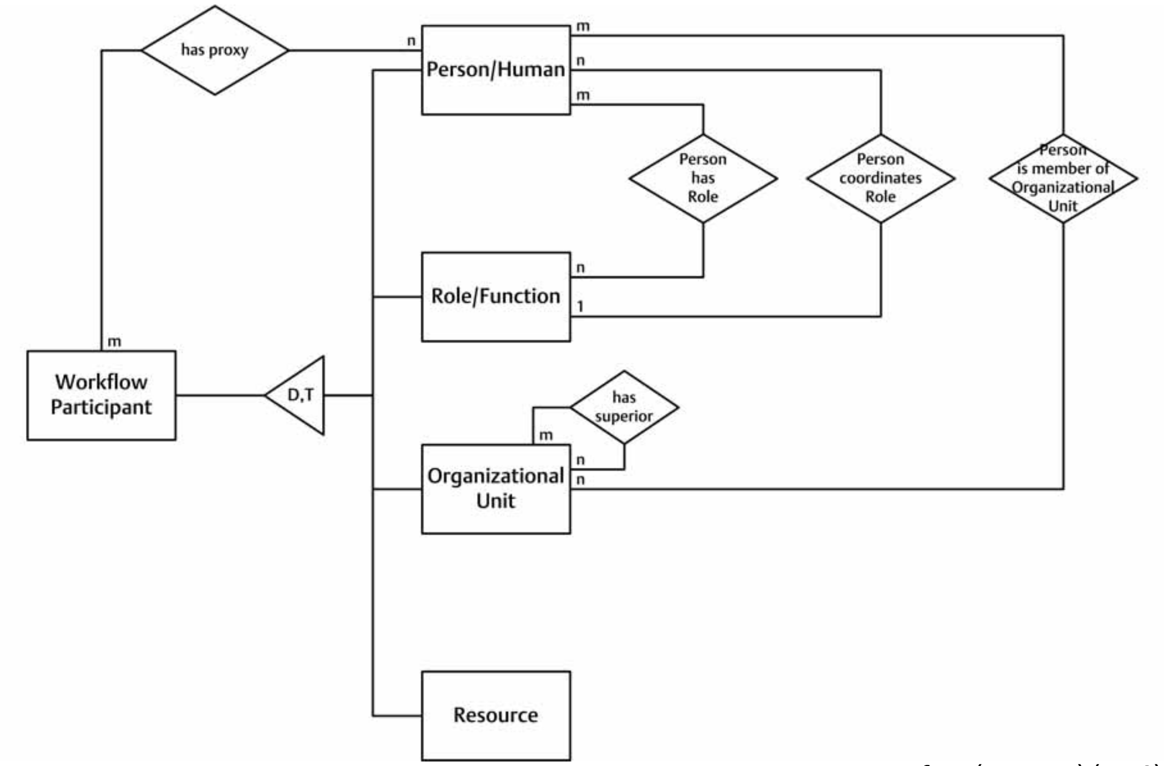


Source: Extended from WfMC (IF1) (1999).

Figure 3-17: WPDL Process Meta Model

WPDL is based on the notion of an acyclic graph, a loop is represented as an explicit loop activity. This is a sub-process that is repeated until a certain exit condition is met. Figure 3-17 shows the meta model of the WPDL process entities as an entity-relationship diagram.

Atomic activities in WPDL are assigned to workflow participants that are either entities of a minimum meta model or entities of an external organization schema that is accessed through a reference to an external repository (e. g., and LDAP schema). The implementation of this external reference is



Source: Compare WfMC (WPDL-O) (1998).

Figure 3-18: WPDL Organizational Meta Model

specified in detail. The minimum meta model distinguishes between organizational units, humans, roles and (technical) resources. Figure 3-18 shows the meta model of the WPDL organizational entities.

Workflow models specified in WPDL can be saved as a text files (or XML documents in the case of XPDL), which facilitates the transfer between modeling tools. In addition to the exchange of models, elements of the WPDL meta model can be created using a subset of the WAPI speficication. These function calls create entities representing meta model elements within a workflow enactment service that supports the relevant API subset. These API commands are listed in the appendix of the Interface 2 & 3 standard, e. g., `WMAddTransition`.[511]

In practice, WPDL and XPDL have found little support in the commercial world, where only few systems use the interchange format for model interoperability. However, emerging Open Source workflow systems such as Enhydra Shark represent their models in XPDL. A process editor called JaWE (Java Workflow Editor) that exports XPDL is available under an Open Source license as well.

511. Compare WfMC (WAPI) (1998).

BPML

The Business Process Management Initiative (BPMI.org) is a industry consortium of approximately 200 companies in the workflow, business process modeling, and systems integration space. It has the mission of developing an XML-based business process modeling language, a matching notation, and a repository for models specified in this language. The initiative was founded in August 2000 under the auspices of Intalio, which produces a BPMI-standards-compliant business process management system and controls much of the regular BPMI operations. The standards defined by BPMI are the *Business Process Modeling Language* (BPML), a matching *Business Process Modeling Notation* (BPMN), as well as a query language for systems operation at run time, the *Business Process Query Language* (BPQL).

BPML was designed as a modeling language for transactional, discrete business processes.[512] Besides entities such as elementary and complex activities, connectors, and events, the BPML meta model offers a number of entities for the management of data at run time (e. g., definition of an activity context, which may contain shared data). In addition, elements for exception handling, such as message, time-out, and failure event handlers are provided. Constructs for the modeling of transactional process segments are available as well. Using such a language construct, a modeler can mandate the idempotent behavior of a process part. I. e., a number of activities are executed and committed in their entirety, or they are rolled back to the state before the activity execution began (this relates to the ACID[513] criteria of database management).[514] Compensation activities can be specified to handle possible transaction failures.[515] The state model of BPML activities and processes is comparable to the WPDL state model and differentiates between the states *ready*, *active*, *completing*, *completed*, *aborting* and *aborted*.[516]

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512. Compare BPMI.org (2002).

513. ACID relates to the desirable properties of a transactional information system: Atomicity (i. e., a transaction is either executed in its entirety or not at all), Consistency (i. e., before and after a transaction is executed the system is in a consistent state), Isolation (i. e., different transactions do not influence another's behavior) and Durability (i. e., after a transaction is completed its results are made persistent). Compare Date (1995), p. 379.

514. Leymann and Roller point out the importance of transactional behavior in workflows: "A workflow management system coordinates the execution of the various activities constituting a single business process. As a result, activity executions of a given workflow share a common fate: they represent a unit of work. The corresponding activities are no longer independent of each other. The failure of one activity might impact other activities. Some activities may have a very strong influence on the overall success of the business process; other activities may have not influence at all." Leymann, Roller (2000), p. 232.

515. For a discussion of compensation spheres in workflow management systems compare Leymann (1996), p. 342 and pp. 346-347.

516. See Arkin (2002).

Parallel to the development of BPML a working group was established to develop a matching process notation. Two different levels of abstraction of this Business Process Modeling Notation (BPMN) are defined. On the one hand, an *execution level notation* will represent the BPML semantics completely. On the other hand, a *business level notation* shall serve as a "lean" notation for organizational modeling purposes, and not contain every detail necessary for the automation of the modeled processes. While the execution level notation contains elements such as fault, compensation, transaction, and context, the business level notation is designed with the intention of a comprehensible graphical diagram, which allows the grouping of elements through swimlanes or participant lanes, respectively. A first version of the BPMN specification was published in 2004.[517]

WSCI

The Web Services Choreography Interface (WSCI) is the official submission of the BPMI.org consortium to the Web Services Choreography Working Group of the World Wide Web Consortium (W3C)[518], the official standards body of the World Wide Web.[519] While BPML and its associated standards are published by BPMI.org as an industry initiative, standards that are officially sanctioned by the W3C have the character of a vendor-neutral standards recommendation. The W3C is working on the standardization of World Wide Web related technologies and protocols, and most standards that relate to Web Services are developed by W3C working groups. WSCI has the status of a W3C note, i. e., it is an input document for the W3C working group that develops a Web Services Choreography Definition Language (WS-CDL).[520]

WSCL

The Web Services Conversation Language (WSCL) was submitted to the W3C by members of the Hewlett Packard research laboratories in February 2002 and was accepted as a W3C note.[521] It represents the results of HP Labs research on the composition of e-services[522], but has not been modified or pursued since its initial submission. Similar to WSCI, WSCL is used as an input document by the WS-CDL working group.

517. Compare White (2004).
518. Compare W3C (2002a).
519. Compare http://www.w3c.org/2002/ws. While the Internet Engineering Task Force (IETF) is responsible for defining technology standards such as the Internet protocols SMTP and TCP/IP, the W3C focuses on higher level protocols such as HTTP and Web Services related standards.
520. Compare W3C (2004).
521. Compare W3C (2002b).
522. Compare Kuno et al. (2001).

WSFL

The Web Services Flow Language (WSFL) was presented by LEYMANN in May 2001 as an extension of WSDL to coordinate the interaction of long running web services.[523] It has since been superseded by BPEL4WS, but to give readers a comprehensive overview of process modeling languages, we are providing a characterization of the language. WSFL can be used to specify the processes within web services, as well as interactions between users and providers of web services.[524]

WSFL consists of two components: *Usage patterns* specify the flows within a web service (i. e., processes with an interface to outside partners), while a *global model* describes the interaction of process partners using web services. The meta model of WSFL is very similar to the meta model if the IBM MQSeries Workflow product[525], only the terminology has been adjusted to match the web service domain. A WSFL *flow* is a directed graph, consisting of *activities*, which are connected through *control links*. Splits and joins in the control flow can be realized through the use of *fork* and *join activities*. For every activity an *exit condition* can be specified in order to refine the control flow. Through this exit condition the correct execution of an activity can be monitored. If the exit condition is not satisfied, the activity has to be repeated. In addition, join activities can be outfitted with a starting condition called *join condition*. The data flow in the process model is represented through *data links* between activities. A flow in its entirety can be supplied with data through an *input link*, and can produce data for outside systems through an *output link*.

The implementation of an activity is realized through a *service provider*. The relationship between activities and service providers is realized in the WSFL model through a reference to a service provider type, which in itself is a collection of WSDL port types. At run time an activity performs a specific operation on the service provider's port that is associated with the activity. The selection of a specific service provider from a pool of similar service providers is based on a locator that states how a service provider is selected at run time (e. g., through a static assignment or through market mechanisms). Relationships between service providers in the global model are represented using *plug links* between the operations of participating service

523. Refer to Leymann (2001).

524. A web service is a well-defined interface to some business functionality, which can be accessed over a network using XML messages. Typically these messages are transported via http, the same protocol used for web pages. Compare Cerami (2002).

525. For a description of the MQSeries Workflow product compare Leymann, Altenhuber (1994); Leymann, Roller (1997); Leymann, Roller (2000). A comparison of the IBM FlowMark meta model (the predecessor of MQSeries Workflow) with other tools can be found in zur Muehlen (1999).

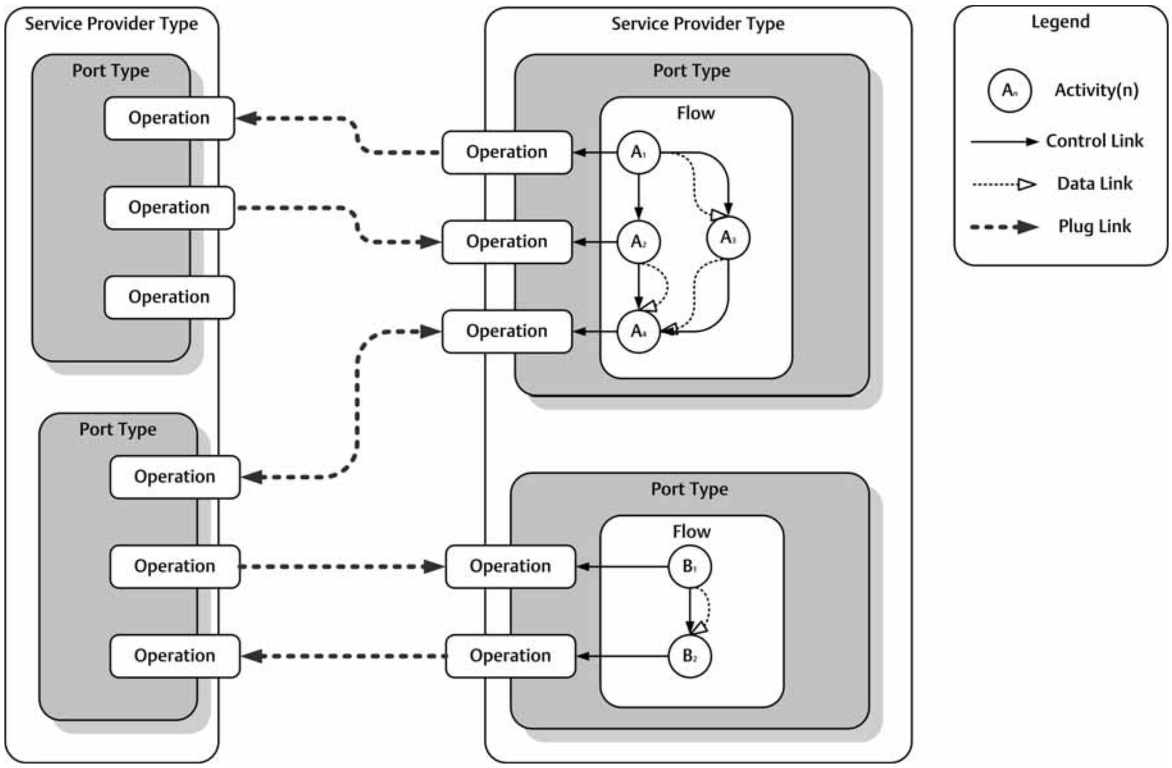


Figure 3-19: Schematic WSFL Flow

providers. Figure 3-19 shows the concept of a WSFL process on the local and global level.

The recursive design of the WSFL specification allows for a re-use of flows as web services in higher-level flows, thus leading to a hierarchical composition of complex web service systems. In the example above, the upper flow consists of three activities (A1, A2, A3), which are implemented through operations. Mirrored operations are implemented as contact points for external service providers or their port types, respectively. For example, activity A1 may invoke a trigger operation. A notification interface is implemented between activity A1 and external systems for this purpose. Activity A2, on the other hand, receives a message from a notification operation. Accordingly, the interface is realized as a trigger operation. Activity A3 has been realized as an internal operation and does not have an external interface. The above example can be specified in WSFL in its entirety. Through the addition of public operations it could be published as a single web service provider.

The specification of web services through WSDL and related processes through WSFL does not contain context information such as legal contracts, price agreements etc. The WSFL specification suggests the use of the Web

Services Endpoint Language (WSEL) for the formal specification of related trading partner agreements.

XLANG

XLANG is a modeling language for business-to-business and enterprise application integration processes which are modeled in the Microsoft BizTalk server.[526] XLANG has been merged with WSFL in August 2002 and is superseded by BPEL4WS. Similar to WSFL, XLANG is presented here to provide readers with background information on the predecessors of BPEL4WS. XLANG processes are specified using a flowchart notation, which is subsequently translated into a the XML format XLANG *schedule*. Figure 3-20 shows a credit application process modeled using the XLANG flowchart notation. XLANG schedules can be interpreted by a version of the Microsoft BizTalk server that works as an integration hub and a workflow engine. Similar to WSFL, XLANG is designed as an extension to WSDL in order to extend the static description of web service interfaces with dynamic behavior. The process modeling constructs of XLANG are thus similar to those of WSFL.

The top-level entity of XLANG is a *schedule*, which consists of one or more *tasks*. Schedules can be linked through message queueing mechanisms, but are independent otherwise. Besides typical model elements such as activities, splits, concurrent activities, and joins, XLANG offers dedicated support for transaction handling. Several activities can be grouped to a *transaction* that is either executed in its entirety or not at all. For each transaction, compensation activities can be specified. These are designed to undo side effects that result from a partial execution of the transaction's activities.[527]

The example process in figure 3-20 shows the process structure on the left side, while the implementation of tasks is indicated through messaging channels on the right side. The tasks "Request Credit Report" and "Receive Credit Report" have been grouped to form a transaction. An XLANG-schedule contains the specification of process data, which can be sent or received via messaging channels. Data mappings between different message formats enable the conversion of messages along a process. For example, an

526. Compare Lebovich, Woodgate (2002); Thatte (2001).

527. An example for a compensation activity is the sending of a correction message. Since messages sent to outside business partners can in most cases not be revoked, the respective party has to be informed about a failure in the process. This example also illustrates that failure handling and compensation activities in inter-organizational processes typically require additional effort and need to be negotiated between the business partners. Compare Stohr, Stohr (2001) for a discussion of possible transaction problems.

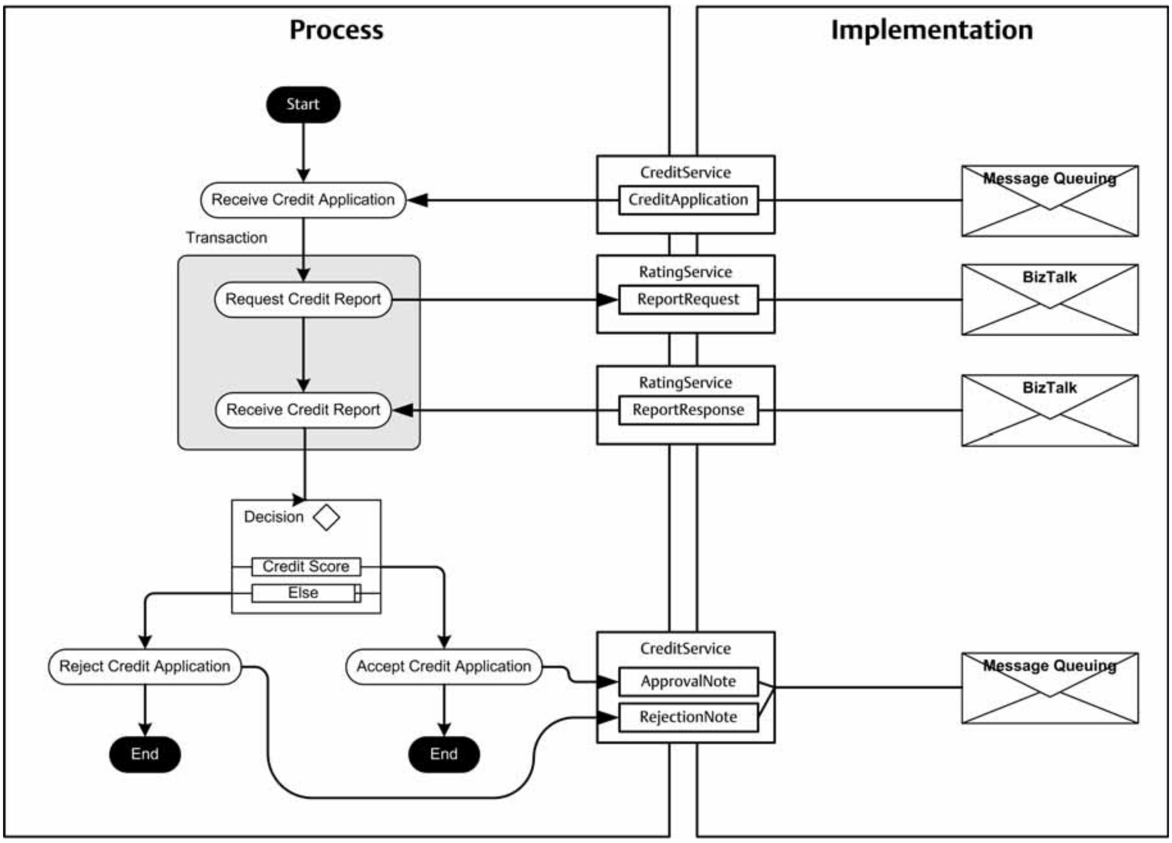


Figure 3-20: XLANG Schedule

incoming EDIFACT[528] message can be converted into an application-specific message format through field-level data mapping.

BPEL4WS

In light of the overlap between WSFL and XLANG, IBM and Microsoft decided to consolidate their efforts in the area of Web Services Choreography.[529] Together with Siebel, SAP, and BEA they founded an industry consortium for the standardization of the Web Services Business Process Execution Language, and a first version of the specification was published in the fall of 2002. The standardization process was handed over to the standardization group OASIS (which also hosts the ASAP working group) in mid-2003.[530] BPEL4WS has generated a lot of interest and is being implemented by software vendors such as SeeBeyond and SAP. It is widely per-

528. Electronic Data Interchange for Administration, Commerce and Transport (UN/EDIFACT) is (besides X12) the most popular pre-XML data format for business-to-business messages, which has been standardized by the International Organization for Standardization (ISO) in 1988. Compare ISO (1988).

529. Compare Leymann, Roller (2004).

530. Attempts by the W3C to receive BPEL as an input document a la WSCI and WSCL failed - amidst other reasons - due to the IP policies of W3C, which require submitters to transfer their intellectual property rights in submissions to the W3C.

ceived as the de facto standard for Web Services Choreography and a number of complementary research projects have emerged.[531] Since the constructs of BPEL4WS are similar to those of WSFL and BPML, which have been discussed above, the interested reader is referred to the BPEL4WS specification, which can be downloaded from the OASIS website free of charge.[532]

Summary

The different process modeling languages discussed above are juxtaposed in table 3-10 using the workflow aspects discussed in section 3.2.2. BPEL4WS exhibits the most comprehensive coverage of the workflow aspects, with the exception of the autonomy perspective, and limitations in the organization perspective. The WPDL/XPDL specification addresses all aspects with the exception of the autonomy and the integrity and failure recovery perspective. However, not all aspects are mandatory for a workflow model specified using WPDL/XPDL. For example, the quality attributes like time and cost are optional attributes, which need not be implemented by all vendors supporting WPDL/XPDL. The more recent standards BPEL4WS, BPML, WSFL and XLANG provide explicit support for failure handling and transaction support, an aspect that is missing from WPDL models. Also, the data handling and mapping capabilities of BPEL4WS, BPML, WSFL, and XLANG are targeted at the integration of heterogeneous data sources. While WPDL/XPDL maintains the distinction between application data[533] and workflow-relevant data[534], the other standards position data integration as a core aspect of their process models.

It is important to note that BPEL4WS, BPML, XLANG and WSFL do not provide constructs for the modeling of process participants or organizational responsibilities. This restricts the use of these modeling languages to fully automated process scenarios, where every activity is either realized through a software function, or where the service implementing the activity has user-handling capabilities of its own. BPEL4WS specifies business partners and partner links for the addressing of external service providers, but the maintenance of organizational structures is not part of BPEL4WS, BPML, WSFL, or XLANG. This indicates the intention of the creators to

531. Compare, e. g., Mendling et al. (2004).

532. See http://www.oasis-open.org/.

533. Application data is defined as “Data that is application specific and not accessible by the workflow management system.” WfMC (Glossary) (1999), p. 54.

534. Workflow relevant data is a subset of application data, made available to the workflow engine on a read-only basis, which is used to determine state transitions of activities and transition conditions, for example, a variable that is evaluated to determine the control flow. Compare WfMC (Glossary) (1999), p. 55.

	WPDL/XPDL	BPML	WSFL	XLANG	BPEL
Function	Workflow Process Definition, composed of Workflow Process Activities and sub-processes	Process, composed of atomic and complex activities	Flow, composed of activities	Schedule, composed of tasks	Business process, composed of activities
Operation	Activities invoke application systems	Atomic activities implement actions, e. g., message exchange	Implemented through service providers. Activities interact with service providers through their operation interfaces. Plug links connect activities and basic operations.	Implemented through service providers. Activities interact with service providers through messaging interfaces.	Activities invoke Web Services, implement control flow constructs, update data containers, or manipulate the state of activities or processes.
Behavior	Transitions between activities Transition conditions be used to restrict the control flow Loop activities can be used for iterations Route activities can be used to split and join the control flow	Implicitly realized through different activity types: ■ all ■ choice ■ delay ■ foreach ■ join ■ sequence ■ switch ■ until ■ while Extensible by encapsulating execution context	Control links between activities Transition conditions be used to restrict the control flow Activities have start and exit conditions to further restrict the control flow	Modeling elements	Implicitly realized through different activity types: ■ sequence ■ switch ■ while ■ pick ■ flow Extensible by encapsulating execution context
Information	Context data is restricted to workflow relevant data, which describes information relevant to the process (e. g., variables for control flow conditions). No provision for application specific data.	Selectors can extract data from messages and map it to properties, which form the process context	Explicit data flow Data links connect activities' in- and output containers Data conversion through data mappings on the data connectors	No explicit data flow Context data contains data objects for all in- and outgoing messages Data mapping between objects provides transformation mechanism	Data scopes define the execution context for activities. Messages can be defined, and their content can be extracted to be used as workflow relevant data.
Organization	Activities are executed by performers Included minimum meta model for the local specification of an organizational model Link to external organizational model for complex applications	Not specified	Not specified	Not specified	Not specified for internal task assignment. External assignment is provided through the definition of partner links and business partners.

Table 3-10: Analysis of different Workflow Modeling Languages

	WPDL/XPDL	BPML	WSFL	XLANG	BPEL
Integrity and Failure Recovery	Not specified	Transactions contexts and compensation activities can be specified. Exception handling can be specified through "fault" activities and event handlers for messages, time-outs, and faults	Not specified	Transaction contexts and compensation activities can be specified	Transaction context and compensation handlers can be specified. Exception handling can be specified through "fault" activities and event handlers for messages, time-outs, and faults.
Quality	Optional process and activity attributes: ■ responsible ■ duration ■ cost ■ working_time ■ waiting_time ■ priority	Not specified	Not specified in WSFL, should be defined in WSEL	Not specified	Deadline and durations are explicitly mentioned and can raise alarms.
Autonomy	Not specified	Not specified	Not specified	Not specified	Not specified

Table 3-10: Analysis of different Workflow Modeling Languages

position these languages in the systems integration space rather than the organizational process space. While this limited view on workflow models results in a reduced complexity for software vendors implementing BPEL4WS-based systems (e. g., they need not worry about access control mechanisms to work items or the representation of heterogeneous organizational structures), the audit trail information that could be provided by such systems does not distinguish between technical resources used for the implementation of an activity, and the resource that carried the organizational responsibility for the activity (e. g., the human performer). In the next section we discuss the representation of organizational structures in workflow models in more detail.[535]

3.5.4 Organization Modeling

A *resource* is an entity that is assigned to a workflow activity and is requested at run time to perform work in order to complete the objective of the activity.[536] A *resource model* contains the definition of human and technical resources that may be used in the execution of a workflow model as work-

535. The section is intended as an overview of organizational modeling in workflow applications. For a more thorough discussion refer to zur Muehlen (2004).

536. For a discussion of different resource modeling approaches compare zur Muehlen (1999). A reference architecture for the organization model within workflow applications was designed by BUSSLER. Refer to Bussler, Jablonski (1995); Bussler (1996); Bussler (1998).

flow participants.[537] The division between a process model on one side, and a resource model on the other side fosters the separate evolution of both models. This has a good reason: The life cycle of human resources within an enterprise typically varies from the life cycle of the enterprise processes. A separation between the two enables workflow designers to create workflow models that are independent of changes in the organizational structure of the enterprise, adding to their robustness. In addition, a separate resource model may be shared by several workflow engines used within one enterprise, reducing administrative overhead and preventing possible redundancies, thereby increasing overall data quality.

Within the reference model of the WfMC, the management of resource information lies within the responsibility of the workflow engine.[538] This reflects the fact that many workflow vendors have implemented proprietary resource management facilities for their workflow management systems. These are either part of the process modeling environment[539] or constitute a separate application.[540] This type of implementation can lead to problems in larger organizations, where several workflow management systems may be involved in the execution of a complex process. These systems cannot share common resource information, which leads to data redundancy. In addition, information such as the workload of individual resources can only be determined, if data from the separate resource management components is consolidated. This data may not be easily accessible - a case where the efficient use of enterprise resources can only be realized locally.

Resource models should satisfy a number of core requirements in order to be applicable to different workflow scenarios. These requirements, which can be derived from general quality criteria for software systems, are robustness, flexibility, scalability and domain independence.[541]

537. We use the term resource model in order not to focus solely on workflow in administrative environments. Workflow management systems may also be used in industrial applications, interfacing with production planning and control (PPC) systems, computerized numerical control (CNC) machines and software agents among others, which have to be defined for use in the workflow management system through the resource model.

538. Refer to WfMC (Glossary) (1999). The WfMC reference model is presented in section 3.4.2 on page 120.

539. Examples for this type of implementation are IBM MQSeries Workflow and the Carnot Process Engine.

540. An example for a separate organizational modeling environment is the Organization and Resource Manager (ORM) by Siemens-Nixdorf, which was a component of the (discontinued) workflow management system WorkParty. The designers of the ORM were influential during the design of the organizational meta model for WPDL (see section 3.4.2 on page 120). For a thorough discussion of the ORM entities refer to Rupietta (1992); Rupietta (1994) and Rupietta (1997).

541. Compare for example the criteria given by Dunn (1991)

- *Robustness*: Changes to the resource model should not affect the workflow model. Moreover, changes to the workflow model such as the addition of an activity should leave the resource model unaffected. Therefore, the resource model needs at least one abstract entity type that serves as a separation between the physical population and the logical address referenced by workflow activities.
- *Flexibility*: The resource model should be flexible enough to allow a transfer of existing organizational structures without requiring a change of the established enterprise terminology or the structure of its organization. For this reason it should be possible to rename entity types and/or to create new entity and relationship types from the resource meta model.
- *Scalability*: The integration of additional levels of hierarchy, new permissions, and obligations should be possible. If a company acquires another company it should be possible to integrate the two organizational models under a single managing authority, possibly by adding new levels to the existing hierarchy.
- *Domain Independence*: A resource model for a collaborative software system should be as domain-independent as possible. There may be situations where only human actors are involved in the execution of a workflow as opposed to situations where only technical resources are involved (e. g., in a manufacturing environment). The resource model has to be flexible enough to handle these variations. In addition, it should only contain a minimum number of entity types in order to preserve maintainability.

Specification of Resource Assignments

Assignment policies describe how a workflow engine matches activities to resources at run time. With regard to the assignment of resources to activities, three different concepts can be distinguished: Direct designation, assignment by role, and assignment using a formal expression.

Direct Designation

Using direct designation, an activity is assigned to one or more entities of the resource model directly. At run time, the workflow-engine can directly look up these resources in the resource repository and place relevant work-items on their respective work lists. This type of assignment is easy to handle for the workflow administrator, because it focuses on a single entity type: the workflow performer. If an activity should be made available to a group of people, all members of the group have to be assigned to the workflow activity individually. The direct assignment concept provides no independence of workflow model and organizational model, i. e., every change of the organizational population is reflected in the workflow model, which has to be changed as well. For this reason, the direct assignment mechanism is rarely used in industrial practice.

Assignment by Role

Many workflow management systems provide workflow modelers with a role construct. Within these systems, one role entity is used synonymously with one or more resource entities. EDWARDS defines a role as a category of users within an application system that inherit a common set of access control rights to objects specific to this application system.[542] The main purpose of the role model is the separation of workflow and resource model. Changes of the organizational population no longer affect the workflow model directly. The use of roles instead of direct assignment also provides means of indirect workload balancing, because all members of a qualified role are notified about a pending work item, but only one member of this group needs to perform the activity. From a technical point of view, the workflow management system has to perform a resolution process to determine the role members before it can notify these resources. An error handling procedure has to be implemented, in case this resolution process returns empty set of resources.

Assignment by Formal Expression

The most complex form of task assignment uses a formal expression, e. g., a predefined function. An example of this type of assignment is the following expression:

```
activity_performer = superior(resource(activity(1)))
```

This expression returns the manager of the workflow initiator, i. e., the resource that performed the first activity of the workflow instance. In this case, not only the entity types of the resource model have to be known to the workflow modeler, but also the relationship types between these entity types, and possible functions that can refer to the workflow execution history. The attributes used in such a formal expression can be dependent on the workflow instance, such as information about the performer of a particular activity. They can also be independent of the workflow instance, such as the relationship of a resource to another resource.

BERTINO ET AL. propose three categories for the classification of formal expressions:[543] Static constraints such as the relationship between organiza-

542. Refer to Edwards (1996).
543. Compare Bertino et al. (1999).

tional units, dynamic constraints that refer to the history of the workflow instance, and hybrid constraints that combine the former two. While static constraints can be evaluated before the workflow instance is started, dynamic constraints can only be evaluated at run time. If a formal expression is used for activity assignment, an error handling mechanism similar to the one used during the assignment by role has to be implemented.

Formal expressions may not only relate to the relationships between entity types of the resource model, but also to specific properties of resources. For the assignment of a meeting room to the activity “perform board meeting”, the location of the room and its availability during a specified time frame may be relevant properties for the assignment process. Therefore, a resource management facility not only needs to handle current information about the workload of resources, but should be able to forecast available capacities, too. Capacity allocation algorithms, such as those used by production planning and control systems (PPC-systems) could improve the resource management component of workflow management systems. This would enable the precise forecast of processing times for workflow instances, thus increasing the quality of responses to customers that are inquiring about the status of their individual workflow instances.

Specification of Assignment Strategies

While resource assignment specifies how a workflow management system identifies matching resources for a pending activity at run time, an assignment strategy (sometimes called assignment policy) specifies how the resource is notified about pending work.[544] Examples are direct allocation, where a single resource is assigned to an activity, and indirect allocation, where a group of resources are notified about pending work, and one of these resources selects the relevant work item. The selection may either be implemented using a scheduling basis (for example: first come first serve, shortest job first), or using a market mechanism such as an open auction for work items.[545]

Design Strategies for Resource Models

We can distinguish between two approaches for resource modeling in workflow applications. These approaches have a direct impact on the design of the resource meta model: The technology-driven approach, and the organization-driven approach.

544. A critical discussion of assignment strategies in commercial workflow systems can be found in Hagemeyer et al. (1998); Hoffmann, Löffler, Schmidt (1999); zur Muehlen (2004).

545. For a discussion of the advantages of direct assignment versus market-based allocation strategies compare Tan, Harker (1997).

Technology-driven Approach to Resource Modeling

The technology-driven approach to resource modeling presumes no predefined set of resources in the organization. Instead, the structure of entity types needed in the workflow model is derived from the specification of the workflow model itself. Typically, roles derived from an existing workflow model are of the form “authorized to perform activity *x*”. This approach enables a lean specification of necessary organization structure, because only workflow-relevant resources have to be captured in the resource model. The use of roles instead of particular resources makes the workflow model independent of changes in the organizational population. However, changes in the workflow model can easily affect the resource model, because newly defined activities require new roles to be defined. A large number of commercial workflow management systems show organizational meta models that were designed following this approach (compare the resource model of Staffware 2000 in figure 3-21).[546] These meta models provide few entity types with fairly restrictive cardinalities. Complex organization structures (e. g., matrix organizations) cannot be represented adequately, if a tool based on such a meta model is used without any extensions.

Figure 3-21: Organizational Meta-Model of Staffware 2000

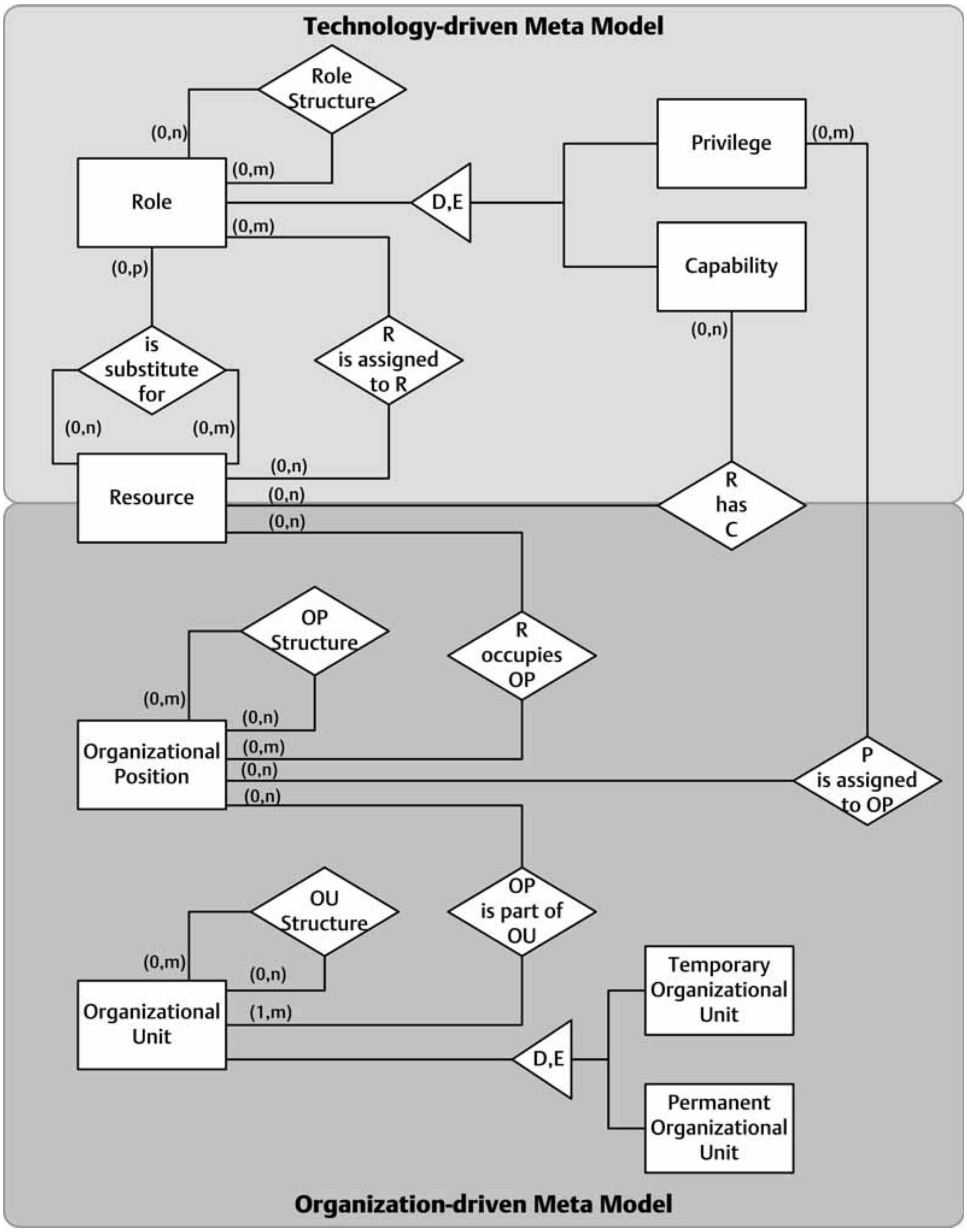
Organization-driven Approach to Resource Modeling

The organization-driven approach to resource modeling can be found in environments where workflow management systems are deployed in larger organizations and a formally defined organization structure is already in place. In this case, the current organizational structure has to be captured in the resource modeling facility of the workflow management system, either by direct modeling or through referral to an external resource repository. Typical examples for such repositories are X.500 directories or the human resources module of an ERP software system.

The advantage of the organization-driven approach is the identity of the organizational structure within the workflow models and the real organization. If workflow models are modified by domain experts as opposed to system administrators it is easier for them to relate to the organizational model depicted in the system. However, many commercial workflow management systems lack basic entities defined in organizational theory, constructs such

546. Another example are the organizational meta models of IBM FlowMark or CSE WorkFlow as described in Rosemann, zur Muehlen (1998).

as organizational position or project team. This conflict can only be resolved if the workflow management system allows the reference to an external repository, or if existing entity types can be modified or enhanced to suit the actual enterprise structure. An example for a semantically rich organization model is depicted in figure 3-22.



Source: zur Muehlen (2004)

Figure 3-22: Organizational Reference Meta Model

Security Considerations

The assignment of workflow activities to a resource may not only depend on the qualification and competencies of the resource, but also on the time of the assignment. For example, a temporary worker in a bank may substitute for a clerk for a limited period of time, therefore, activity assignments resulting from this substitution should only be active during this specified time frame. Furthermore, the planning of organizational development may be performed a considerable time before it is being activated. In the HR module of the mySAP ERP-System this fact is represented using different organizational plans within the organizational development module HR-PD, while only one of these plans is activated. The resource management facility has to ensure that, e. g., the promotion of a resource can be put in effect either immediately or at a specified point in the future. ADER proposes the handling of security information as an additional entity type within the resource meta model.[547] In order not to increase the complexity of the resource model we propose the implementation of time constraints for roles should be handled at the attribute level, e. g., by adding the attributes “valid_from” and “valid_through” to the entity type role. If an activity becomes assignable during this time, it may be assigned to the resources that are members of this role. The workflow management system or the resource management facility, respectively, have to ensure that work items can only be selected during the activation period of the role identified for their initial assignment. If an activity has been assigned to a resource based on a competency and has not been executed when the competency is revoked, the work item has to be removed from the work list of this resource. The tracing of this information may become increasingly complex, especially if a work item is transferred from one resource to another by means of delegation or substitution.

For auditing purposes it should be possible to trace the changes of a resource profile, e. g., the granting and revocation of privileges over time. Therefore, a resource manager should implement a version concept that stores relationships between roles and resources with the beginning and end of validity. For purposes of process controlling, information about the current responsibilities and authorizations in the resource model is necessary, should a post-execution audit of workflow instances be desirable. Information about the organizational structure is also useful to identify social networks between workflow participants that may impact process performance.[548]

547. Refer to Ader (1996).
548. Compare van der Aalst and Song (2004).

3.5.5 Application Integration

A workflow management system supports process participants through the provision of application logic for the execution of their activities. Alternatively, it performs activities without user interaction through the automated invocation of application logic or services.[549] The specification of application integration modalities in a workflow model ranges from the specification of scripts within activities, which are executed by the workflow engine when the activity is enacted, to the design of integration adapters for external application systems or web services.[550] The use of applications in activities can be either mandatory (for example, if data is passed to and received from the application), or optional (for instance, if the workflow management system offers the performer of an activity a support application for an otherwise manual task).[551]

If external applications are referenced within activities, the workflow model contains information about the access mechanisms (i. e., how the application is invoked). This application invocation can be asynchronous, if the workflow engine triggers the execution of an external application, but does not wait for this application to finish. More frequently used is the synchronous invocation of applications, when the workflow engine waits for a signal from the application (or the user) to indicate the availability of result data. If data is passed to and received from the application, the workflow model may need to specify how data is transformed into and from the format of the external application. If the external application fails, the workflow model should specify if the same activity can be executed again without affecting the public result of the activity. This is critical if preliminary application results may be visible to outside parties while the activity is being executed (side-effects). In this case, compensation steps for aborted or failed activities need to be specified.[552]

External applications manipulate data stores that are not directly accessible to the workflow management system, but that may be accessible to other applications or users of the same application outside of the workflow context.[553] The workflow modeler has to specify mechanisms to ensure the integrity of data that the workflow instance passes to and receives from external applications.

549. Compare Böhm (2000), p. 167.
550. Some workflow management systems provide complex programming capabilities, including the handling of user interfaces for data entry and processing. Compare for example Staffware (Functions) (2000). These systems allow the specification of workflow applications without the use of external application systems.
551. Refer to Böhm (2000), p. 169.
552. Refer to Böhm (2000), p. 171.
553. Refer to Böhm (2000), p. 169.

Contemporary workflow management systems rely on messaging and integration infrastructures, such as application servers[554], which standardize the communication between the workflow engine and external systems, simplifying the application integration process for workflow developers significantly. Compare figure 3-5 on page 118 for a workflow service in an application server architecture. The application server contains adapters to external systems, such as ERP software, database applications, or legacy applications. The workflow developer has to specify interfaces to these adapters, but not to the external systems directly. The standardization of web services protocols such as WSDL and SOAP will continue to ease systems integration, as the loose coupling of applications via their web services interfaces is becoming increasingly popular.

3.6 Use of Workflow Applications

In the previous section we have focused on the design of workflow applications, covering aspects from process and organizational design to the integration of external application logic. In this section we focus on the use of workflow applications at run time.

3.6.1 Run Time Behavior

The run time environment of a workflow management system can be accessed from three perspectives:

- *Workflow participants* interact with their own work list handlers. Through this interface they are informed about pending work items, can select these work items for further processing, and are guided to invoked applications, if the relevant activity has been implemented in this way. Workflow participants can use the monitoring facility of the workflow enactment service to consult the history of a particular workflow instance (e. g., to identify the colleagues that worked on a particular case), or to evaluate the overall load of the workflow engine (e. g., the number of pending activity instances, running processes, users logged on to the system, etc.).
- *Workflow administrators* and *process managers* interact with the workflow engine through an administration interface. They can reassign work items to different workflow participants (e. g., to level the work load in different departments). In addition, they can monitor the overall

554. An application server is responsible to provide a standardized run time environment for an application system. Thus run time environment provides services such as transaction management, scalability, platform independence and the functionality to access front- and back-end systems in a transparent manner. Compare Schlumpberger (2001), p. 48.

performance of the workflow engine, either at a technical level (administrator) or at an organizational level (manager). The information provided by workflow management systems for these groups of users is discussed in chapter 4.

- *Workflow customers* interact with the workflow management system through its process invocation interface. They trigger the creation of workflow instances and may manipulate the status of these workflow instances from the outside, if permitted (e. g., they may start, suspend, and stop workflow instances). A direct interaction between workflow customers and the workflow enactment service is less common. Instead, the application programming interface of the workflow engine is typically encapsulated by a front-end that enables workflow customers to use the functionality they are authorized to access. A workflow customer can also be represented through an application system. If, for instance, the receipt of an e-mail triggers the instantiation of a workflow, this process invocation is realized at a technical level through the mail server sending a “create workflow instance” command to the mail daemon of the workflow engine.

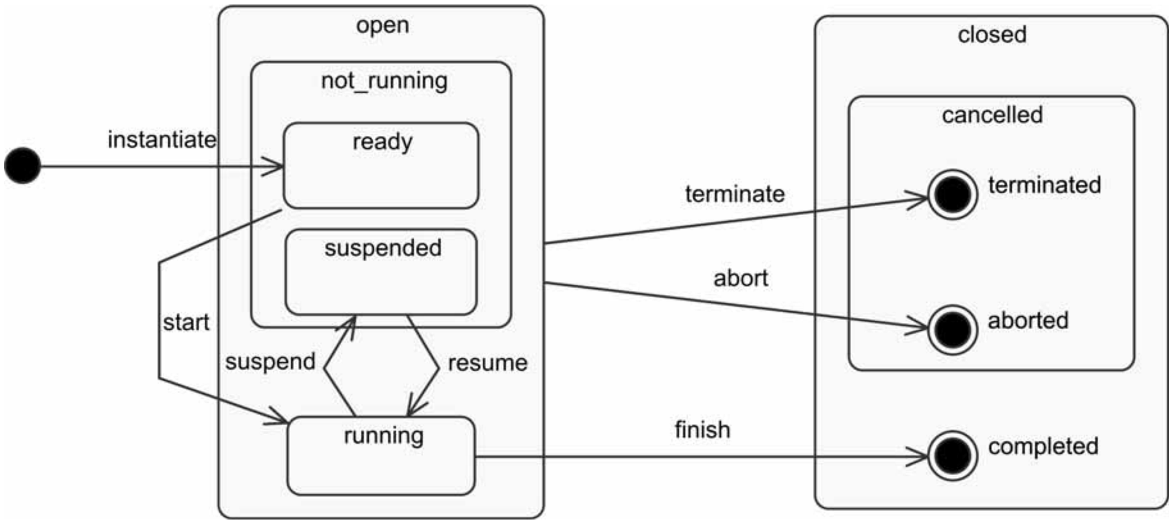
3.6.2 Workflow Instance State Model

During each phase of its enactment, a workflow instance maintains a well-defined state. This state may be modified through the workflow engine or through an external entity interacting with the workflow engine.[555] Figure 3-23 shows the state model of a workflow instance in form of a UML state diagram.[556] The model is composed of the two super-states `open` and `closed`. A workflow instance in the state `open` can be manipulated through the workflow engine or an external entity, while a workflow instance in the state `closed` is finished and cannot be reactivated. Within the super-state open, the workflow instance is either `not_running` (meaning that its activity instances are not being worked on) or `running` (meaning that activity instances are created, assigned, and can be executed).

An open workflow instance can be finished either by completion, or by forced termination. In the latter case, the resulting state can be `closed.cancelled.aborted`, if running activities at times of the cancellation command were allowed to finish (this is also known as a *graceful* abort). If the cancellation of the workflow instance leads to the immediate

555. The WfMC WAPI contains a number of commands for this interaction, for example `WMFetchProcessInstanceState` or `WMChangeProcessInstanceState.` Refer to WfMC (WAPI) (1997), pp. 23-44.

556. For details of the notation refer to the notation guide in the appendix.



(compare WfMC (1997), p. 172ff.; Alonso, Mohan (1997), p. 5)

Figure 3-23: Generic State Model of a Workflow Instance

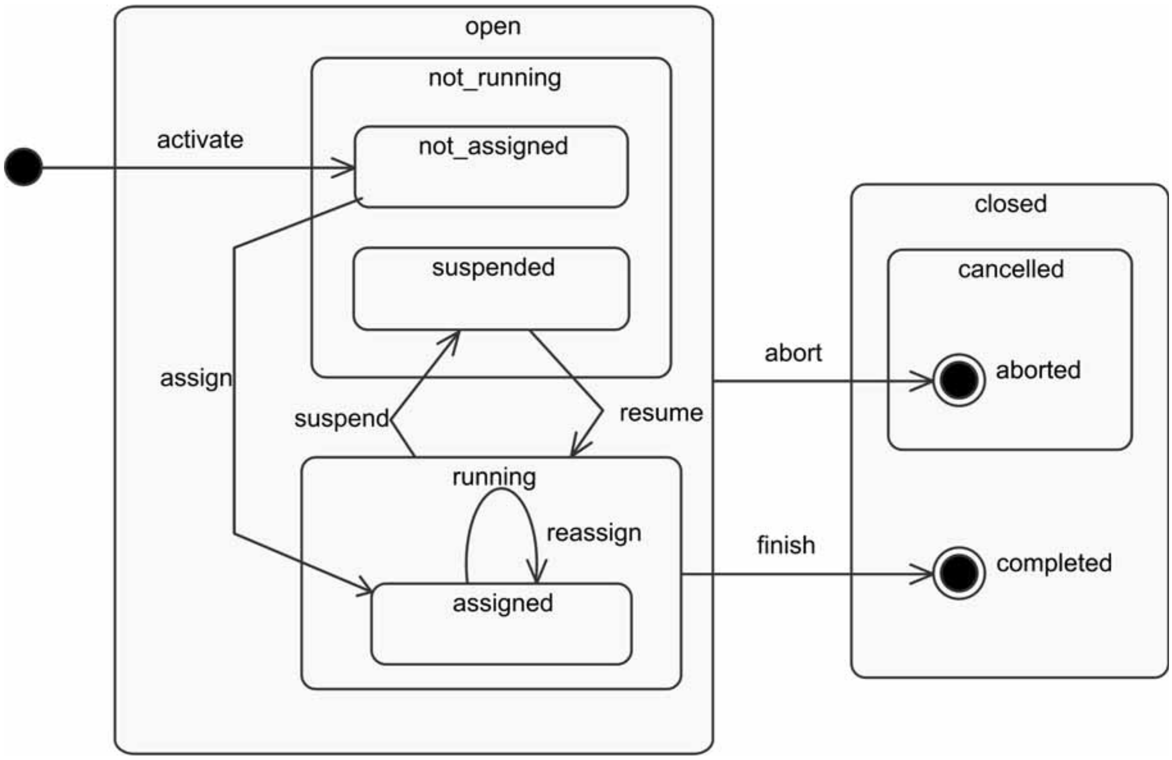
cancellation of running activity instances, the resulting state is `closed.cancelled.terminated` (this is also known as a *forced* abort).

3.6.3 Activity Instance State Model

Similar to workflow instances, each activity instance follows a life-cycle that can be described using a state model. Figure 3-24 shows the state-change-diagram for a typical activity instance.[557] Like the state-change-diagram for the workflow instance itself, this model consists of several nested states. An activity instance is either in the state `open`, and can be assigned, started, suspended etc., or it is in the state `closed`, if it has been completed or cancelled. Upon activation by the workflow engine, an activity instance is in the state `open.not_running.not_assigned`, indicating that it has not been assigned to a particular workflow participant.

If the activity instance is assigned to an arbitrary number of workflow participants (i. e., via a role or an organizational entity such as a department), the activity instance will be visible to all authorized participants through a work item on their shared work list. Once a participants selects the work item representing the activity instance for further processing, the activity instance changes into the state `open.running.assigned`. This transi-

557. The state-transition diagram in figure 3-24 is not based on an actual workflow management system. The nested states have been taken from the WfMC state models, see WfMC (WAPI) (1997), pp. 174 ff. Figure 3-24 does not distinguish between activity instance state and work item state, instead, this information is embedded in the “assigned” and “not_assigned” sub-states. A different state model for an activity instance can be found in Alonso, Mohan (1997), p. 6, who explicitly incorporate start and end conditions into the state model. The model presented here incorporates these constraints through guard conditions on the transitions to the state `open.not_running.not_assigned` (start condition) and from the state `open.running.assigned` to the state `closed.completed` (end condition). If either condition is not met, the corresponding transition must not be traversed.



(compare WfMC (1997), p. 172ff.; Alonso, Mohan (1997), p. 6)

Figure 3-24: Generic State Model of an Activity Instance

tion may also be traversed automatically, if the activity is assigned directly to a particular workflow participant, or if the activity is executed without the involvement of a (human) participant. In this case, the assignee is the workflow engine itself. Some systems allow users to reject work items, in this case the transition may be traversed in the opposite direction.

An assigned activity may be suspended and resumed an arbitrary number of times. It also may be reassigned to a different workflow participant (recursive transition from the state `open.running.assigned` to the (same) state `open.running.assigned`). If a workflow participant refuses to perform an assigned activity, the activity's state changes back to `open.not_running.not_assigned`. From any of the sub-states of the `open` superstate, the execution of the activity may be cancelled, resulting in a transition to the state `closed.cancelled.aborted`. A closed activity instance cannot be reactivated, but (system constraints permitting), the same activity may be re-instantiated. A successfully completed activity instance has the state `closed.completed`.

3.6.4 State Changes and Constraints

While the state models in figure 3-23 and figure 3-24 provide a general overview of the execution dynamics at run time, additional constraints may limit the ability of the workflow engine to traverse between certain states.

These constraints include the start and end conditions of activities, which determine their eligibility for activation or completion, respectively. Also, the transition between different states of a workflow instance or activity instance is not always permitted, depending on the state of other system elements. If, for example, a workflow instance is to be suspended (transition from `open.running` to `open.not_running.suspended`) while there are open activity instances, the behavior of the process instance can be implemented in different ways by the workflow vendor:

- The open activities are not affected by the suspension and their continued execution is permitted. Upon completion (or termination) of the activity instances, the workflow engine does not evaluate the outgoing transitions from the completed activities, until the workflow instance is resumed. This way, the effect of a workflow instance suspension is not noticeable to workflow participants. There may be a considerable time-lag between the suspension of the workflow instance and the completion of the last running activity.
- All open activities are suspended until the workflow instance is resumed. This way, the suspension of a workflow instance is immediately noticed by those workflow participants, whose activities are suspended by an external authority. Also, applications that perform changes on external data sources may need to lock these data sources for as long as the workflow instance is suspended. Effectively, they are prohibiting other applications from accessing this data for an arbitrary period of time.
- All open activities are aborted, and when the workflow instance is resumed, the activities are executed again. If the granularity of activities is coarse, intermediate results that are visible to external applications may need to be compensated.

The above example shows that log information of the type “a certain workflow instance is in a certain state at a certain time” needs to be enhanced with information about the semantics of the implementation, otherwise it may not be possible to resume the execution of workflow instances without damaging the integrity of surrounding applications and data stores.

3.6.5 Audit Trail Information

Most workflow engines record state transitions at the activity and workflow level (as well as certain system events, such as user log-on or log-off) in a log file or database, called the *audit trail*.[558] Depending on the implementation of the workflow engine, the quality of data recorded in the audit trail varies significantly. Audit trail information is being kept by workflow systems for a variety of purposes:

- *Recovery purposes.* Like the system log of a database system, the audit trail file of a workflow system contains information about open and closed (in the sense of completed) workflow and activity instances. In case of a system failure the workflow engine can use the audit trail upon restart to restore the last known system state. The system has to consider potential side-effects created by activities that were running at the time of system failure.[559]
- *Workflow execution purposes.* The audit trail file typically contains information about the resources associated with particular events (if these events were caused by a workflow performer). This information can be used by the workflow engine to determine the performers of upcoming activities. For instance, in an administrative workflow such as a travel expense settlement, the notification about reimbursement approval or decline should be sent to the workflow participant that started the workflow instance. Since several members of the organization are authorized to start a travel expense reimbursement workflow, the workflow participant responsible for the notification activity cannot be specified in the workflow model at build time. Instead, the workflow engine can use audit trail entries of the current process instance to determine the process starter and use this information for the presentation of the next work item.[560]
- *Evaluation purposes.* Since the audit trail provides accurate and timely information about the execution of workflow and activity instances, this information can be used in the context of process monitoring and controlling. We discuss this aspect in detail in the following chapter.

558. Some authors use the term workflow log as a synonym for audit trail, compare Agrawal, Gunopulos, Leymann (1998). GEPPERT and TOMBROS refer to the audit trail as event history (Geppert, Tombros (1997), p. 67). SCHLUNDT ET AL. as well as KOKSAL ET AL. use the term history management, see Schlundt, Jablonski, Hahn (2000) and Koksal, Alpinar, Dogac (1998). MCLELLAN distinguishes between the audit trail as the raw data collection and workflow metrics as evaluations based on this data (McLellan (1996), p. 303).

559. For a discussion of recovery aspects compare e. g. Eder, Liebhardt (1996) and Liu et al. (2000).

560. Of course, information about the process starter could also be treated as a workflow relevant data object and stored in the workflow engine for the duration of the workflow instance.

4 Workflow-driven Process Controlling

In the previous two chapters we have determined the organizational, managerial, and technological factors that play a role in the design and application of workflow-based process monitoring and controlling systems. In this chapter we outline the architecture of such a system. We start with a review of related work in section 4.1. In section 4.2 we develop a reference model for workflow audit trail data, a central basis for process monitoring and controlling systems. The design of a conceptual framework, a reference architecture for process controlling systems is discussed in section 4.3, and in section 4.4 we return from the more technical aspects of process controlling to the organizational implementation, and present a process controlling cycle based on the cybernetic controlling models discussed in chapter 2.

4.1 Related Work on Workflow-based Monitoring and Controlling

The use of workflow audit trail information for controlling purposes has been recognized by the scientific community only recently. The first survey of the analytical opportunities arising from audit trail information was provided by McLellan in 1996.[561] He provides an overview of the analysis of historical process data and discusses the evaluation of audit trail data in terms of workflow metrics. The controlling applications described in his article are statistical evaluations as well as the run time detection of late cases and overdue tasks. Since the publication of McLellan's paper, a number of scientific and commercial approaches to process monitoring and controlling have been published. Recently, the monitoring of business processes has been branded as Business Activity Monitoring by the Gartner Group.[562]

Existing work on the monitoring and controlling of processes can be classified in four areas:

- Data Perspective: How to collect, store, and represent process audit trail data.
- Usage Perspective: Management of exceptions versus the management of regular process operations.
- Tool Perspective: Architectures and prototypes of process monitoring and controlling systems.
- Method Perspective: Conceptual approaches to process monitoring and controlling.

561. See McLellan (1996).
562. Compare Dresner, McCoy (2002); Dresner (2003).

4.1.1 Data Perspective

WfMC Common Workflow Audit Data Format

The Workflow Management Coalition has specified an interface for workflow audit data in the context of their generic workflow reference model.[563] The WfMC Interface 5 specifies the elementary information a workflow management system should record the execution of workflow instances.[564] The existing standard provides a data format for the audit trail data as well as guidelines, which events should be recorded. However, the evaluation of this information is not addressed in the WfMC standard. After the publication of the current standard document, a proposal for an API has been submitted to the WfMC,[565] but since the revision of the data format in 1999 little progress has been made in providing either a functional specification or an XML schema for audit data.

4.1.2 Usage Perspective

Computer-based Process Performance Measurement (COPPA)

The COPPA project (Computer-based Process Performance Measurement) conducted at the University of Fribourg, Switzerland, deals with the design of a performance measurement system.[566] Using a three stage approach, the authors first surveyed the market and corporate practice of performance measurement. During a second stage the architectural and functional requirements of a performance measurement system were outlined, and during a third phase, a prototype of the performance measurement system was implemented. In relation to workflow-based controlling, the authors position process performance measurement at a higher level of abstraction, which includes information about the strategic positioning of an enterprise, whereas a workflow-based controlling system is mainly focused on the analysis of operational data.

Chimera-Ex

In the EU-funded project WIDE project, CASATI ET AL. investigated the issue of specifying and monitoring exceptions in workflow management systems which are most applicable for standard and repetitive business processes.[567] The authors introduce an exception language Chimera-Ex to

563. Compare Hollingsworth (1995).
564. See WfMC (IF5) (1999).
565. Compare WfMC (IF5 API) (1999)
566. See Kueng (1998), Kueng (2000).
567. Compare Casati et al. (1999); Casati et al. (2000).

model the exceptional situations for the workflow according to detached active rules and patterns. The authors applied the language in the proposed architecture FAR and integrated it with a commercial workflow management system. The authors address exception handling in the context of workflow management in some extent, however, all exceptions that can be managed by this architecture are described at build-time, i. e., unpredictable exceptions are not considered.

Process and Project Management

The capabilities of workflow technology in controlling and monitoring business processes and project management were discussed by SHIH and TSENG in 1996.[568] They compare the similarities and differences in the conceptual characteristics of business processes and project management, as well as their respective management needs in the functions of planning, execution, monitoring, and controlling. The authors propose a workflow technology-based system with capabilities to handle concurrent coordination, monitoring, and communication in business processes and large-scale projects. An implementation of the proposed system is not provided.

4.1.3 Tool Perspective

WorkFlow Analyzer

The design of a process analysis tool named WorkFlow Analyzer was presented by DERSZTELER as part of his Ph.D. work.[569] A partially functional prototype was implemented on the basis of CleverPath Forest&Trees. Based on audit trail data from the workflow management system WorkParty by Siemens Nixdorf and target data from the business process modeling tools ARIS and Bonapart, the prototype provides several quantitative evaluation methods. However, the combination of the audit trail information with business data was not realized in this approach. In addition, the platform-specific implementation and the reliance on a single (and discontinued) workflow management system limit the general applicability of his approach.

IDWM - Process Controlling in the Manufacturing Domain

A more process-specific prototype was developed by RAUFER, who discussed the controlling of workflow-based processes using a case study from the manufacturing domain.[570] He focused on a specific process, which was enhanced with cost information as well as target work- and cycle-times. The

568. Compare Shih, Tseng (1996).
569. See Derszteler (2000).
570. See Raufer (1997).

presented prototype, based on the workflow management system COI, is targeted specifically at the process analyzed by RAUFER. As a result, the system architecture cannot be generalized easily.

Workflow-driven Activity-based Costing

A similar prototype was presented by WEISS.[571] He developed a workflow-driven activity-based-costing system for the commercial workflow management system Staffware. The focus of his approach is the realization of a single evaluation method, therefore, the resulting system is not designed to be extended by additional evaluation methods.

PISA - Process Information System based on Access

The research project CONGO (Controlling and Monitoring of distributed Workflows for continuous Process Improvement) was conducted between 1995 and 1999 at the University of Münster, Germany, and is the predecessor of the research project presented in this book.[572] Over the course of this project, three process controlling system prototypes were implemented, called PISA (Process Information System based on Access) I, II and III.

PISA I was developed in the fall of 1995 as a working prototype based on a Microsoft Access database. The system was able to access process models from IDS Scheer's ARIS Toolset Version 3.0 through an ODBC connection, and imported the audit trail file from IBM FlowMark Version 2.2. This first version served as a feasibility study and implemented elementary evaluation methods based on a cube with the dimensions process, abstraction, and organization. Whereas the first prototype employed only a few evaluation methods, PISA II (also based on Microsoft Access) used more sophisticated evaluation methods, such as the hedonic wage model[573], and allowed additional evaluations on process objects, such as a cluster analysis.

PISA III was re-implemented in Java with the goal to realize a fully distributed system architecture. In addition platform, database, and client independence should be realized. The PISA III Server is a stand-alone application that coordinates the PISA clients and delivers evaluation methods, the matching graphical panels to display evaluation results, as well as the results of audit data evaluations. The PISA client is realized as a Java applet that can be executed within a Java-capable web-browser. Data source adapt-

571. See Weiß (1998).
572. Compare Rosemann, Denecke, Püttmann (1996); Rosemann (1997); zur Muehlen, Rosemann (2000); zur Muehlen (2000).
573. Compare Sassone (1987).

ers work as mapping modules to connect the contents of a workflow audit trail database with the audit trail repository of the PISA III system. These adapters perform conversions between system-specific data formats and provide transparent access to data sources, enabling the system to integrate the audit trails of different workflow systems.

Process Performance Manager

The Process Performance Manager is a commercial performance analysis tool by IDS Scheer AG which can connect to different application systems.[574] The system mainly integrates source data from modules of the mySAP ERP system into a relational database and calculates predefined ratios. These ratios are frequency- and time-related and computed at different aggregation levels, reflecting recipients at the operative level, middle management, and executives. Workflow-vendor Staffware has integrated the Process Performance Manager with its workflow management system, and offers a customized version of the Process Performance Management as an OEM product for their Staffware 2000 workflow management system.

Business Process Intelligence

CASATI ET AL. at Hewlett Packard Laboratories have developed a Process Data Warehouse for the collection of metrics from the workflow management system HP Chang*e*ngine.[575] They propose the use of process mining algorithms to derive behavioral patterns from workflow audit trail information. As a front-end they propose a Business Process Cockpit, which uses multi-colored bargraphs to illustrate time-based process attributes, such as the processing times of individual activities.

IBM Solution Manager

JENG and SCHIEFER have developed an agent-based architecture with the aim of providing continuous, real-time analytics for business processes.[576] For the analytical processing they introduce an agent framework that is able to detect situations and exceptions in a business environment, perform complex analytical tasks, and reflect on the gap between current situations and desired management goals. A more recent project of SCHIEFER, JENG, and BRUCKNER aims at bridging the gap between existing workflow management systems and decision supporting systems, since they are not able to provide continuous, real-time analytics for decision makers.[577] In their

574. Compare IDS Scheer AG (2000).
575. Compare Casati et al. (2002); Bonifati et al. (2001).
576. Compare Jeng, Schiefer (2003).
577. Compare Schiefer et al. (2003).

paper, the authors introduce an agent-based architecture to support a business intelligence process to sense, interpret, predict, automate, and respond to changes in business processes in a timely fashion.

The proposed architecture is composed of five major components: Business Intelligence Agents for analytical processing; An event processing container (EPC) for the real-time transformation of process events; A Process Information Factory for storing business process metrics (i. e., a process-specific data warehouse); A policy management system for monitoring/ tracking all management agents running within the system; And a dashboard for the visualization of business process metrics and analytical results. In a later paper, SCHIEFER extended the Solution Manager architecture to expose its functionality through four web services interfaces, for the set-up of the solution manager, monitoring of running processes, analysis of data in the process warehouse, and the feeding of event data.

4.1.4 Method Perspective

Workflow-driven Balanced Scorecard

MCGREGOR has analyzed the existing WfMC common audit data format standard in order to design a process controlling prototype that uses this information to generate the process perspective of a balanced scorecard.[578] Her work aims at the development of a closed-loop system that takes audit trail information as an input and delivers advice to process designers, regarding which aspects of the workflow model could be optimized. She discusses the impact of process controlling requirements on the WfMC Interfaces 1 and 5, and proposes extended attributes for the integration in the standards specification.[579] The analysis is based on a case study and is performed on a conceptual level and served as input to the IW-MONS framework.

IW-MONS

MCGREGOR and KUMARAN have presented a Solution Management framework that analyzes workflow audit logs, utilizing decision support system principles and agent technologies to feedback performance measures. This framework forms part of the Intelligent Workflow Monitoring System (IW-MONS) methodology.[580] An extension for this framework using web services was proposed by MCGREGOR and SCHIEFER, who state that current

578. See McGregor (IF5) (2002).

579. It should be noted that the attributes proposed for an extension of Interface 5 are already covered by the Prefix part of the existing specification, which is presented in section 4.2.2 on page 183.

580. Compare McGregor (IW-MONS) (2002); McGregor, Kumaran (2002).

web service frameworks do not include the functionality required for web service execution performance measurement from an organizational perspective.[581] The work of McGregor remains at a conceptual level, without a physical implementation.

*Workflow*BPR*

Shohaiep et al. present a methodology for the identification of process knowledge through the analysis of work practices.[582] Even though their method is called "Workflow*BPR" it does not require the use of a workflow management system. Taking the basic idea of determining the knowledge incorporated in a process, workflow audit trail data can be perceived as a "knowledge store" in its own right. For example, the experience of a workflow participant could be computed taking the number of times into account that this participant has performed a certain activity type. When this information is fed back into the workflow management system, new staff allocation methods could be implemented, such as "assign this activity to the most experienced person available". The paper by Shohaiep et al. remains at a conceptual level and does not discuss implementation details.

4.2 A Reference Meta Model for Audit Trail Data

4.2.1 Information Content of Audit Trail Data

The content of audit trail data that is available for subsequent analysis in process controlling systems is determined by two factors: The event types recorded by the workflow management system during the enactment of workflow instances, and the types of attributes recorded with each audit trail entry. The combination of these two factors determines the amount and quality of raw data available for further analysis. In the following section we analyze the audit trail data format of three commercial workflow management systems and compare these with the common workflow audit data format proposed by the Workflow Management Coalition.[583]

Systems Analyzed

For our analysis we have chosen three systems that represent a spectrum of classical and contemporary workflow products: IBM MQSeries Workflow, Staffware 2000, and Carnot Process Engine.

581. Compare McGregor, Schiefer (2003).
582. See Shohaiep, Housel, Kanevsky (1997).
583. Compare WfMC (IF 5) (1999).

The *IBM MQSeries Workflow* system was first released in 1994 under the name FlowMark, a name that was maintained until the release of version 2.3. At this point, the core workflow system was re-implemented, replacing the original communication infrastructure with support for the IBM MQSeries message queueing middleware, and the system's name was changed to match the new infrastructure support. Prior to the re-implementation, FlowMark was used as the basis platform for a research project at IBM Almaden Research Center, which addressed distribution, transaction management, and messaging aspects of the workflow infrastructure.[584] The system was included in the evaluation, because its development has been well documented[585], and it has been analyzed in previous research projects.[586]

Staffware was one of the first workflow vendors that offered a pure-bred workflow product and has competed in the workflow market since the middle of the 1980s.[587] The workflow management system Staffware 2000 has been a commercial success with more than 1,000,000 licensed clients, and the largest installation covering 10,000 users.[588] The Staffware 2000 system provides support for the display of process metrics and its audit trail can be extended with user defined entries. This system was included for its commercial availability.

The *Carnot Process Engine* represents a workflow management system based on an application-server-based software architecture.[589] Instead of being an independently executable application, the workflow engine is deployed in a J2EE compliant application server that provides infrastructure services such as messaging support, adaptors to legacy systems, and database connectivity. The Carnot Process Engine stores workflow models and audit trail information in a combined database structure. This system was chosen as a representative of a new generation of workflow products that leverage infrastructure standards. Carnot entered the marketplace 15 years after the first version of Staffware was released, and 6 years after the release of IBM FlowMark. For this reason, the three systems represent a sample of workflow management systems with different maturity.

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584. The Exotica project resulted in two prototypes that extended the functionality of FlowMark. Exotica/FMDC added capability for the handling of mobile and disconnected clients. Compare Alonso, Agrawal et al. (1996). Exotica/FMQM added support for a message queueing infrastructure layer. Compare Alonso et al. (1995). In addition, work on the support of advanced transaction models was performed. Compare Alonso, Günthör et al. (1996).

585. Compare e. g. Leymann, Altenhuber (1994); Leymann, Roller (1997); Leymann, Roller (2000).

586. Compare Rosemann, Denecke, Püttmann (1996).

587. Compare figure 3-1 on page 93.

588. Compare Karl, Karl (2000), p. 50.

589. Compare Carnot AG (2002).

4.2.2 Audit Trail Attributes

The attributes stored in a workflow management system's audit trail determine the integration points of the audit trail entries with additional data sources. For instance, if a workflow management system stores the identifier of the business object that was manipulated during the execution of an activity instance, this reference can be used to enhance the audit trail information with business-object-related information from data sources outside the workflow management system's scope.

Workflow Management Coalition Interface 5

As part of the WfMC reference model, the specification of Interface 5 provides guidance for workflow vendors with regard to which data should be captured and stored in the audit trail of a workflow management system. The intention of the common workflow audit data format (CWAD) is the integration of audit trail information across different workflow management systems and different processes to enable enterprise-wide and cross-enterprise process analyses.[590] Figure 4-1[591] shows the data structure proposed in the WfMC Interface 5 specification.[592] It consists of a *prefix*, a variable *body*, and a *suffix*. The prefix contains the identifier of the process instance, which caused the audit trail entry. In order to support hierarchical processes, each entry contains the identifier of the root process instance (i. e., the direct superior instance to the current instance, if applicable). The body of the data structure varies for different types of events. The suffix data structure is used for vendor-specific extensions of the data model. Using different extension types, vendors can record additional attributes depending on the events their systems are capturing.

The different data structures of the CWAD body can be grouped into process-related events, activity-related events, and work-item-related events. The state change of a process instance (e. g., the cancellation of the process instance) causes the previous state of the process instance to be recorded. In contrast, the state change entry of an activity instance contains both the previous and the current state of the activity instance. The current state of the process instance is part of the prefix data structure.

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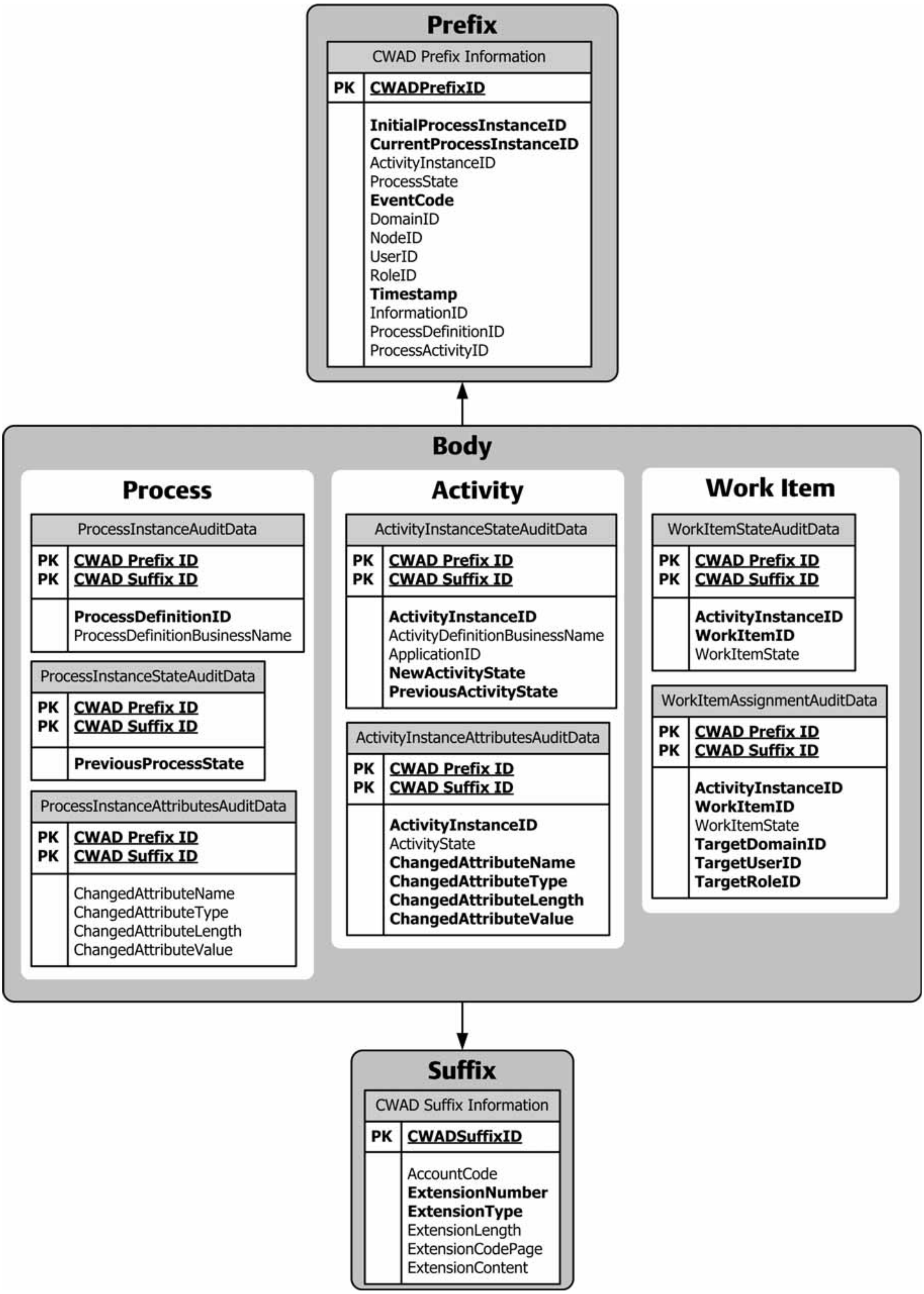
590. Compare WfMC (IF5) (1999), p. 5.

591. The data structures are presented in object-relational notation. Bold attribute names indicate mandatory attributes, while plain type attributes are optional (i. e., the table may contain a NULL value for this attribute). The indicator "PK" denotes a primary key, while "FK" denotes a foreign key.

592. Note that audit trail entries concerning the remote invocation of processes have been omitted from the diagram. These entries are designed for the consistent recording of processes that are implemented across different workflow engines. For the purpose of this study, we restrict the analysis to processes that are executed on a single workflow engine.



Source WfMC (IF5) (1999).

Figure 4-1: Audit Trail Data Structure of WfMC Interface 5

This example illustrates the varying number of attributes recorded for different event types. On the one hand, this allows the workflow engine to record only those attributes that are relevant for the current event, thereby reducing the number of NULL valued fields. On the other hand, the consistent storage of audit trail information is hampered through the changing data structures for different event types. Ultimately, the workflow management system needs to maintain seven different log entry formats to be compliant with the Common Workflow Audit Data format.

IBM MQSeries Workflow

The audit trail of IBM MQSeries Workflow is recorded in a single table structure with fixed attributes as shown in figure 4-2. While the audit trail is recorded in the database of the workflow engine, the single table structure enables the system to export the audit trail entries in a single file or message, simplifying the integration of this type of data into evaluation tools. Nevertheless, since not all recorded attributes are relevant for all types of events, a number of NULL values will be recorded for most events. For example, the transfer of a work item for the activity instance *review invoice* between the workflow participants *zur Muehlen* and *Becker* in the process instance *invoice illbruck* of the workflow model *invoice auditing* creates the following audit trail entry:

```
2002-06-01:13:05:05:001,21009,invoice illbruck,
PID4711,invoice illbruck,PID4711,,P01,invoice auditing,
2002-05-01,,zur Muehlen,Becker,review invoice,
21100,21200,,,WID001,work item001,,,
```

The attributes of the audit trail contain a field with information about a second user. This field is used when a work item is transferred or duplicated. In this case, the second user field contains the user who was the source of the transfer or duplication. The field is also used when a work item is created: This event is initiated by the workflow engine, thus the first user field refers to the workflow engine itself, and only the second user field contains the name of the work item recipient. The attribute second activity name is filled in conjunction with events created by transitions, and contains the name of the target activity a transition is leading to. The field *associated object* contains the object identifier of the work item, activity instance, or process instance the event was recorded for. This value is different from the regular identifier, since it can be used to locate the associated object in the underlying audit trail database.

Audit Trail	
PK	**ID**
	Timestamp **Event** **Process Name** **Process Identifier** **Top-level Name** **Top-level Identifier** Parent Process Name Parent Process Identifier **Process Model Name** Process Model Valid From Date Block Names User ID Second user ID Activity Name Activity Type Activity Status Second Activity Name Command Parameters Associated Object Object Description Program Name Activity Return Code

Source: Compare IBM Corporation (1999), pp. 37-45.

Figure 4-2: Audit Trail Data Structure of MQSeries Workflow

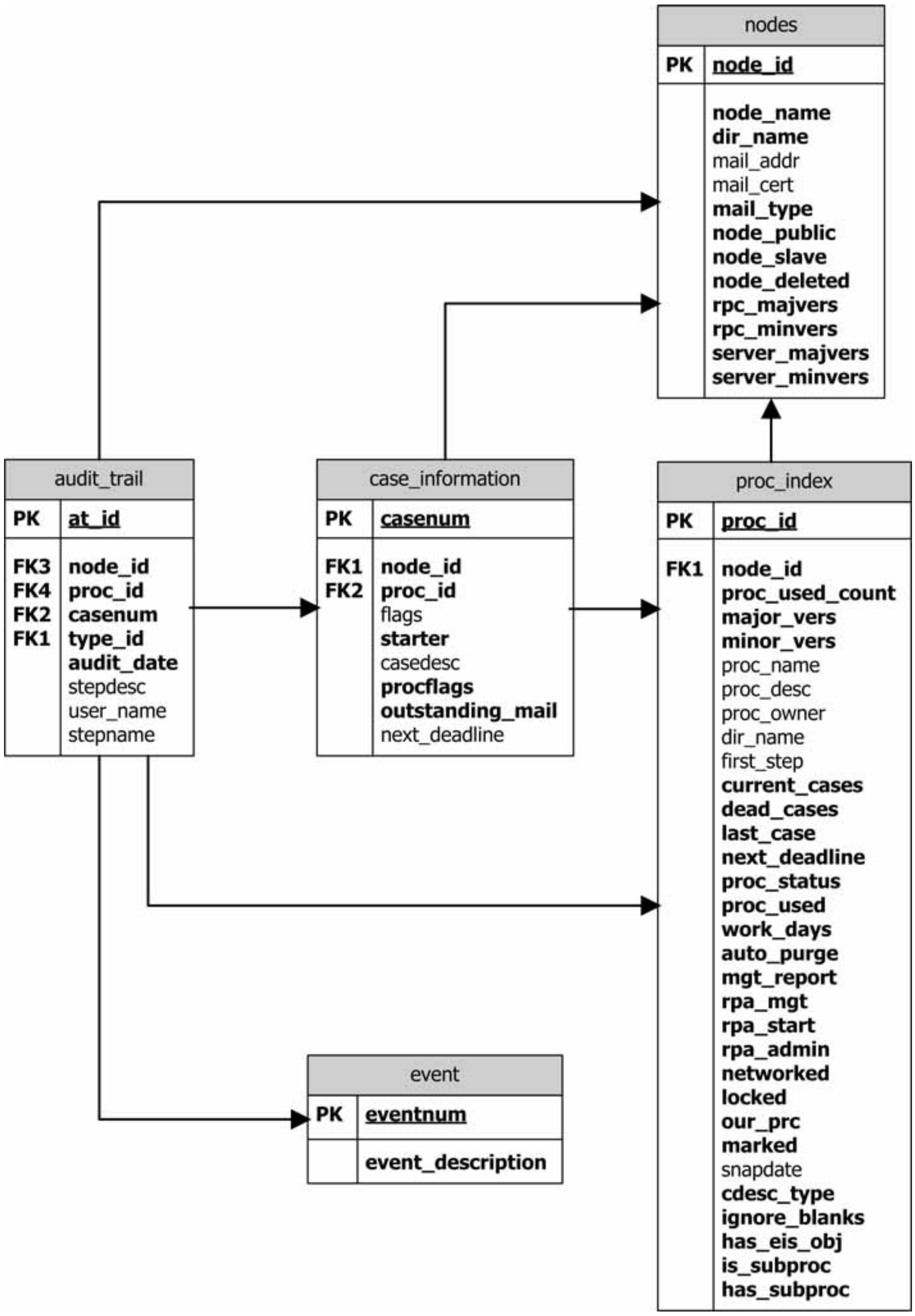
Staffware 2000

Figure 4-3 shows the audit trail data structure of Staffware 2000. While the core audit trail record contains only eight attributes, it provides links to the data structures for process instances (*case_information*), process models (*proc_index*) and network structures (*nodes*). The events recorded in the audit trail table are defined in a text file, which specifies a 3-digit event code and a description of the event. This format makes it possible for system administrators to enhance the existing event codes with user defined event codes.

The Staffware audit trail table does not provide information about super- or sub-processes in a direct manner. Instead, this information is stored in the proc_index table (attributes *is_subproc* and *has_subproc*), since support for hierarchical processes was only added for an upcoming product version, but the version analyzed in this book did not support hierarchical processes.

Carnot Process Engine

The audit trail database structure of the Carnot Process Engine consists of four categories of tables (compare figure 4-4). The tables on the left side of the diagram contain the process structure of the workflow model, while the tables on the right side of the diagram contain the entities describing the organization model. The tables in the middle of figure 4-4 contain data about the running and completed workflow instances. Instead of a central

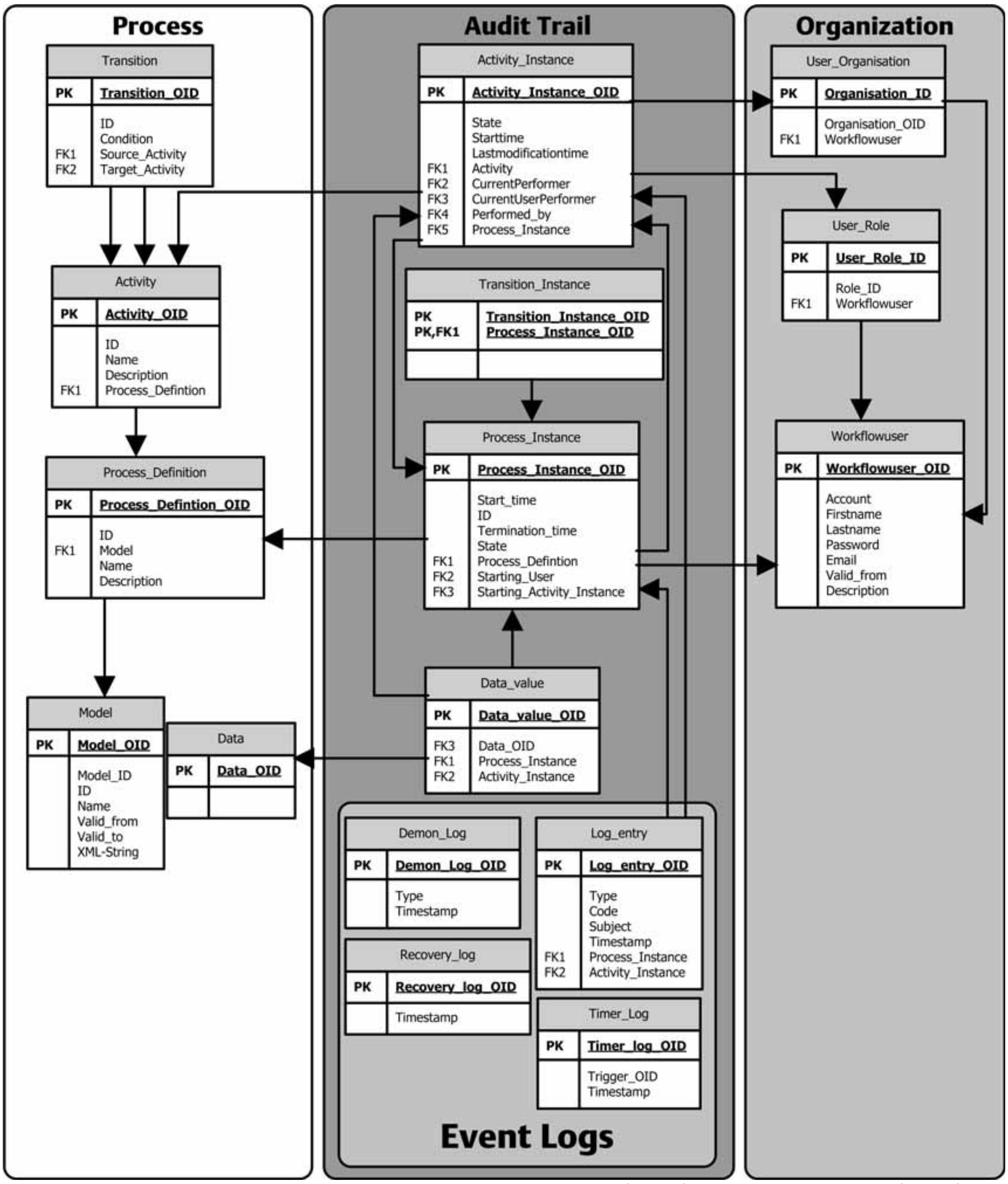


Source: Compare Staffware plc (Oracle) (2000).

Figure 4-3: Audit Trail Data Structure of Staffware 2000

audit trail table, the Carnot Process Engine maintains four log tables that record events that are produced by the workflow engine, the timer daemon, or recovery tasks, i. e., when the state of running process instances is restored after a system failure. The *daemon_log* table records events documenting the behavior of system daemons, such as the mail daemon that monitors incoming e-mails and triggers processes upon the receipt of relevant e-mail messages.

The *log_entry* table contains the audit trail entries created by the workflow engine during the enactment of workflow instances. Other than a timestamp



Source: Compare Carnot AG (2002), pp. 273-279.; Blum (2002), p. 17.

Figure 4-4: Audit Trail Data Structure of Carnot

and the type of event (subject), it only contains references to the process instance object and activity instance object associated with the log entry. Information about the originator of the event is stored with the object itself. For instance, the activity instance table contains information about the performer of an activity instance. This combination of attributes improves the performance of process monitoring queries, such as “who was the performer of the last activity”, since no database joins are required to identify the performer of an activity. Still, the manipulation of activity instances, e. g., the delegation of an activity instance to another user, cannot be determined ex-post, since the activity instance table only contains one attribute for the actual performer of an activity.

4.2.3 Audit Trail Events

In addition to the attributes recorded by the workflow engine, the granularity of information stored in the audit trail depends on the event types which result in audit trail entries. The WfMC Interface 5 distinguishes four categories of event types: Workflow instance related events, activity instance related events, work item instance related events, and remote operation audit trail information. The last type of events is recorded, if a workflow engine manipulates activities or processes that run on a remote workflow engine, or if it is being manipulated through a remote system in a similar fashion. This type of information enables a consolidated recording of audit trail information in one place, even though the logical workflow instance in question was executed across different systems. For the first three event categories, the WfMC specification differentiates between the following event types:[593]

Process Instance Audit Information

These events relate to state changes at the process instance level, such as the instantiation, start, and completion of workflow instances.

Create/Start Process/Subprocess Instance Audit Data

- `WMCreatedProcessInstance`: A new process instance was created.
- `WMStartedProcessInstance`: A process instance was started.

Change Process/Subprocess Instance State Audit Data

- `WMChangedProcessInstanceState`: The state of a process instance has changed due to an external or internal event.
- `WMCompletedProcessInstance`: A process instance has been completed normally.
- `WMTerminatedProcessInstance`: A process instance has been terminated (i. e., gracefully canceled before it was completed, pending activities and sub-processes may still be active).
- `WMAbortedProcessInstance`: A process instance has been aborted (i. e., forcefully canceled before it was completed, all pending activities and subprocesses have been cancelled as well)

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593. Compare WfMC (IF5) (1999), p. 30-31. Events regarding the remote invocation of processes or activities have been omitted from the list.

- `WMWaitingOnEvent`: A process instance is waiting for event(s) to occur.[594]
- `WMEventOccurred`: One or more event(s) on which a process was waiting has occurred.
- `WMStartedSubprocess`: A subordinate process has been started by a process instance. This information is used by the workflow engine to determine, if a process instance has any pending sub-processes, in case the top-level process instance is aborted.
- `WMCompletedSubprocess`: A subordinate process has been completed and control is returned to the parent process (in case of a synchronized instantiation).

Assign Process Instance Attributes Audit Data

- `WMAssignedProcessInstanceAttributes`: One or more attributes of a process instance have been changed. Using this event, a workflow engine can signal that a process instance has exceeded the maximum permitted processing time, and an escalation was raised. Other possible uses could be changes in process ownership, or a change of process quality parameters, such as priority or deadlines.

Activity Instance Audit Information

The events relate to state changes at the activity instance level, such as the availability or completion of an activity.

Change Activity Instance State Audit Data

- `WMChangedActivityInstanceState`: The state of an activity changed due to an external or internal event. This entry is also used to record the initial state of the activity instance. In this case, the state of the activity would be changed to “ready”.
- `WMCompletedActivityInstance`: An activity instance has completed successfully. The workflow engine may be notified about this event through a variety of mechanisms. Either the workflow participant has signaled the completion of the tasks associated with the activity, all work items connected with the activity have reported completion, or an invoked application has transmitted a successful completion code.

---

594. Note that the WfMC specification does not support the handling of events. Therefore, this audit trail entry only relates to workflow engines capable of handling events, but is not mandatory for all workflow engines supporting the Interface 5 specification.

- `WMTerminatedActivityInstance`: An activity instance has been terminated (i. e., it has been ended gracefully).
- `WMAbortedActivityInstance`: An activity instance has been aborted (i. e., it has been ended forcefully).
- `WMWaitingOnEvent`: An activity is waiting for one or more event(s) to occur.
- `WMEventOccurred`: One or more events have occurred an activity was waiting for.

Assign Activity Instance Attributes Audit Data

- `WMAssignActivityInstanceAttributes`: One or more attributes of an activity instance have been changed. Similar to a process instance, changes of activity instance attributes can signal the occurrence of an escalation, or general property changes of an activity.

Work Item Audit Information

These events relate to state changes of work items, i. e., elements that represent activities to process performers.

Change Work Item State Audit Data

- `WMSelectedWorkItem`: A user has selected a work item from his or her work list. The activity associated with the work item is associated with the respective user and is locked from access by other users, unless it is a group activity where several users are required to complete the activity. This event type also covers the reservation of a work item for later processing, and the checking out of a work item for processing on a device that may be disconnected from the workflow engine.
- `WMStartedWorkItem`: A user has started working on tasks represented by a work item. Within most workflow management systems this event coincides with the selection of a work item. If work items are presented on work lists that are shared by several users it may be desirable to reserve a work item first, and start working on it later.
- `WMChangedWorkItemState`: The state of a work item has been changed by an external or internal event. This event type is also used to indicate the initial state of a work item.
- `WMCompletedWorkItem`: All tasks related to a work item have been completed successfully.

- `WMRejectedWorkItem`: A work item has been rejected by a user. If work items are offered for user selection this situation should not occur often. Nevertheless, if the workflow engine “pushes” pending activities to users through the use of scheduling algorithms, users should have the option to refuse a work item presented to them.

Assign/Reassign Work Item/Work List Audit Data

- `WMAssignedWorkItem`: A work item is placed on the work list of a user, i. e., it is made visible to the user for selection.

- `WMReassignedWorkItem`: A work item has been reassigned to one or more users different from the original recipient.

- `WMReassignedWorklist`: The entire work list of a user has been reassigned to one or more users.

4.2.4 Comparing the Information Content of Audit Trails

Table 4-1 lists the workflow instance-related events recorded by the three commercial systems. Table 4-2 contains the corresponding activity instance-related events. As a reference, the event types supported by the WfMC Interface 5 specification including the event name are listed as well.[595] Since Staffware and Carnot do not differentiate between activity instance events and work item events, these event types have been combined into one table.

IBM MQSeries Workflow

The audit trail functionality of MQSeries Workflow offers both a concise and a verbose option for audit trail recording. Using the concise option, only a limited number of event types are logged, but more technical events are not recorded in the audit trail. Using the verbose option, additional technical events are recorded in the audit trail. Almost all event types specified by the WfMC specification are supported, with the exception of a process abort.

For some event types, such as the suspend and resume events on the process and activity level, the original user request as well as the system response are recorded. For example, if the user requests the suspension of a process, the system may actually set the state of the process to “suspended” only when all pending activities and sub-processes have been completed. This may result in a delay between the request and response events.

While the level of detail provided by the MQSeries Workflow audit trail enables a very detailed analysis, the events recorded by the workflow engine may result in potentially large amounts of data. LEYMANN and ROLLER have

595. Compare WfMC (IF5) (1999)

	Event	IBM MQSeries Workflow V 3.2	Staffware 2000 V 8.1	Carnot Process Engine V 2.0	WfMC Interface 5
Workflow Instance Event	ready	x	o	x	x (WMCreatedProcessInstance)
	start	x	x	x	x (WMStartedProcessInstance)
	suspend	x (request and result)	o	x	x (WMChangedProcessInstanceState)
	resume	x (request and result)	o	x	x (WMChangedProcessInstanceState)
	terminate	x (error and requested)	x (error and requested)	x	x (WMTerminatedProcessInstance)
	abort	o	o	o	x (WMAbortedProcessInstance)
	complete	x	x	x	x (WMCompletedProcessInstance)
	overdue	x	x	x	x (WMAssignedProcessInstance-Attributes)
	restart	x	o	o	x (WMChangedProcessInstanceState)
	delete	x (request and result)	o	o	o
	other	■ Import ■ Exit condi-tion failure	■ user revisions ■ user-defined events	■ schema changes	■ Remote process invocation ■ Remote process control ■ Event (wait/received) ■ Attribute changes

Table 4-1: Audit Trail Entries (Workflow Instance)

pointed out the risk of growing audit trails.[596] They estimate the typical number of log entries per activity to be five, equalling 1 KB for a fully featured audit trail entry. For a medium sized company that executes 10,000 process instances with 10 activities per day, this calculation results in an audit trail of 500 MB every day, not including the associated business object information. Numbers like these are not unusual. The average number of pages received in the mail room of the insurance company described in chapter 5 is on average 29,000 per day, resulting in 8,900 different process instances that are instantiated every day.

Staffware 2000

The Staffware audit trail format offers fewer event types than proposed by the WfMC Interface 5 standard. For instance, even though the system supports the interruption of activity instance processing in the form of suspend and resume operations, these events are not recorded in the audit trail. This makes it impossible to determine the actual (productive) processing

[596] See Leymann, Roller (2000), p. 106.

	Event	IBM MQSeries Workflow V 3.2	Staffware 2000 V 8.1	Carnot Process Engine V 2.0	WfMC Interface 5
Activity Instance Events	ready	x	x	x	x (WMChangedActivityInstanceState)
	assign	x (work-item)		x	x (WMSelectedWorkItem/ WMAssignedWorkItem)
	start	x	x	x	x (WMStartedWorkItem)
	reassign	x (work-item)	x	o	x (WMRejectedWorkItem/ WMReassignedWorkItem)
	suspend	x (request and result)	o	x	x (WMChangedActivityInstanceState)
	resume	x (request and result)	o	x	x (WMChangedActivityInstanceState)
	complete	x	x	x	x (WMCompletedActivityInstance/ WMCompletedWorkItem)
	abort	x	x (error and requested)	x	x (WMAbortedActivityInstance)
	overdue	x (two-level)	x	x	x (WMAssignedActivityInstance-Attributes)
	other	■ Mobile events (check-in/out) ■ Duplicate work-item ■ Process and activity import	■ Mail delivery events ■ Sub-case events ■ Withdrawn and resent activities ■ User-defined events		■ Reassignment of entire worklists ■ Event wait and receipt ■ Change of activity instance attributes

Table 4-2: Audit Trail Entries (Activity Instance)

time of an activity as opposed to idle time; only the general turnaround time of an activity instance can be computed. In correspondence with system functionality, Staffware supports the withdrawal of work items from user work lists, and the resubmission of these work items to the same or different users at a later point in time, and these events are recorded accordingly in the audit trail.

While the lack of standardized event types limits the expressiveness of the Staffware audit trail, the system allows for the definition of custom event types (up to a maximum of 743 user defined event types), which can be inserted into the audit trail.[597] This enables the recording of additional information related to a workflow instance, for example, the identifier of the business object related to the current workflow instance. This additional information is not recorded automatically, instead, a manual system function has to be invoked to trigger the insertion of a custom audit trail entry. Con-

597. Compare Staffware plc (Oracle) (2000).

sequently, the additional audit trail entries have to be specified during the design phase of the workflow model and appropriate (automated) activities have to be inserted into the workflow model at build time.

Carnot Process Engine

The Carnot Process Engine records almost all event types defined by the WfMC specification in its audit trail database. Only state changes on the work item level are not recorded, because the workflow engine does not distinguish between an activity instance and a work item. Consequently, the performer attributes related to a work item are associated with the activity instance, not the state change recorded in the audit trail.

4.2.5 Conceptual Workflow Meta Model

In order to create a framework for process controlling based on workflow audit trail data, it is necessary to determine the entities contained in a workflow audit trail. Figure 4-5 shows the conceptual workflow meta model, which outlines the elements and relationships that contribute to the workflow audit trail. This meta model is based on the activity-centered process modeling paradigm, although it could be adjusted to accommodate different approaches with relatively little effort. The left side of the entity-relationship diagram contains a conceptual model of the workflow modeling method, while the right side shows the entities related to run time dynamics. All elements of the reference meta model have been outlined in chapter 3, and more detailed definitions can be found there.

Build Time Elements

A *process* (which may be hierarchically decomposed) consists of *activities.* The activities are connected through *transitions*, and one activity may have multiple incoming and outgoing transitions. Activities without an incoming transition are start activities, activities without outgoing transitions are end activities. Transitions may contain *transition conditions*, which restrict the control flow. A transition condition may refer to a property of a *business object*. A business objects is a coherent collection of data that describes an economically relevant object that can be manipulated through one or more *applications.* Activities may reference a business object relevant application, unless they are executed manually. In this case, the *performer* of an activity manipulates a business object outside the control sphere of the workflow application.

Run Time Elements

At run time, *process instances* are created from the process models defined in the build time phase. A process instance contains one or more *activity instances*, which are presented to workflow participants for selection and execution. Note that an activity instance belongs to exactly one process instance, whereas an activity (at the model level) may exist independent of a process model, or may be reused in different process models. A *work item* is the representation of a particular activity instance for a particular workflow participant. While the activity instance contains run time information that can be interpreted by the workflow engine, e. g. invocation parameters for an associated application, the work item contains performance instructions for potential workflow participants (candidate performers). Other run time elements, such as application functions or business object instances, have been omitted from the diagram for reasons of clarity.[598]

Audit Trail (State Model)

Process instances, activity instances, and work items each are in exactly one specific *state* at any given point in *time* (e. g., ready, assigned, started, completed, terminated). For this reason, the state of a process instance (activity instance, work item) is modeled as a ternary relationship between the entity types process instance (activity instance, work item), state, and time. The state of these entities may change over time. Transitions between process, activity, and work item states are modeled as relationship types over the respective state entities. This explication of state transitions can be used for subsequent extensions, such as the modeling of transition constraints, which restrict the space of state transitions to a limited number of legal state transitions.

The modeling of time as an independent entity type allows for the specification of time points and time periods.[599] The structure relationship type over the entity type time allows for the combination of different time constructs. For example, if an activity instance is repeatedly suspended and resumed, the total suspend time of the activity can be computed through the combination of the individual suspend times. The time identifier is used to denote the type of temporal construct represented by the time entity (e. g., open-ended period, closed period, combined period). The audit trail of a

598. This omission reflects the principle of relevance as stated in the Guidelines of Modeling, compare Becker, Rosemann, v. Uthmann (2000), p. 32.

599. Refer to Becker, Schütte (1996), pp. 161-162, who use this notion of time for the modeling of purchasing conditions in retail enterprises.

workflow management system records the state changes of the three entity types process instance, activity instance, and work item.[600]

4.2.6 A Reference Data Structure for Audit Trail Information

Based on the findings of the exploratory analysis in section 4.2.2 and 4.2.3 we can now develop a reference data structure for audit trail information. Figure 4-6 shows the reference meta model for audit trail data.

Overall Structure

An *audit trail* contains one or more *events*, but it may be empty as well. An event occurs at a specific *time*. Several events may occur simultaneously. An event is caused by an *originator*, who is either a *workflow participant*, or a *workflow engine*. Workflow participants cause events when they actively manipulate the objects presented to them by the workflow engine. The workflow engine causes system events, such as the change of a process instance attribute (e. g., if a process instance exceeds a deadline). An event is represented as a ternary relationship type between the entity types time, event type, and workflow object. It exhibits a strong relationship with the entity types originator and audit trail, respectively.

An event describes the state change of exactly one affected *workflow object*. A workflow object is either a *process instance*, an *activity instance*, or a *work item*. An event can be classified as belonging to an event type, for example, the event type “created” defines the class of events such as “activity instance 4711 created at 09:32:01 by user zur Muehlen” and “process instance 0815 created at 03:15:00 by workflow engine”. Two corresponding start and end event types define a *state*. States may be nested to form a hierarchy, as described in the states models in section 3.6.2 and section 3.6.3.

Dimension Clusters

The audit trail meta model in figure 4-6 is marked with several dimension clusters, in order to illustrate which areas of the meta model can be refined for further analysis. The entity type workflow participant is the anchor point for the r*esource dimension*. A workflow participant typically belongs to an organizational unit and covers a certain role. Navigating through the workflow audit trail, a process analyst could use these relationships to group audit trail entries by organizational context. For example, he or she could determine,

[600] Note that some systems do not differentiate between activity instances and work items. In these cases the states of the work item are represented in the states of the corresponding activity instance.

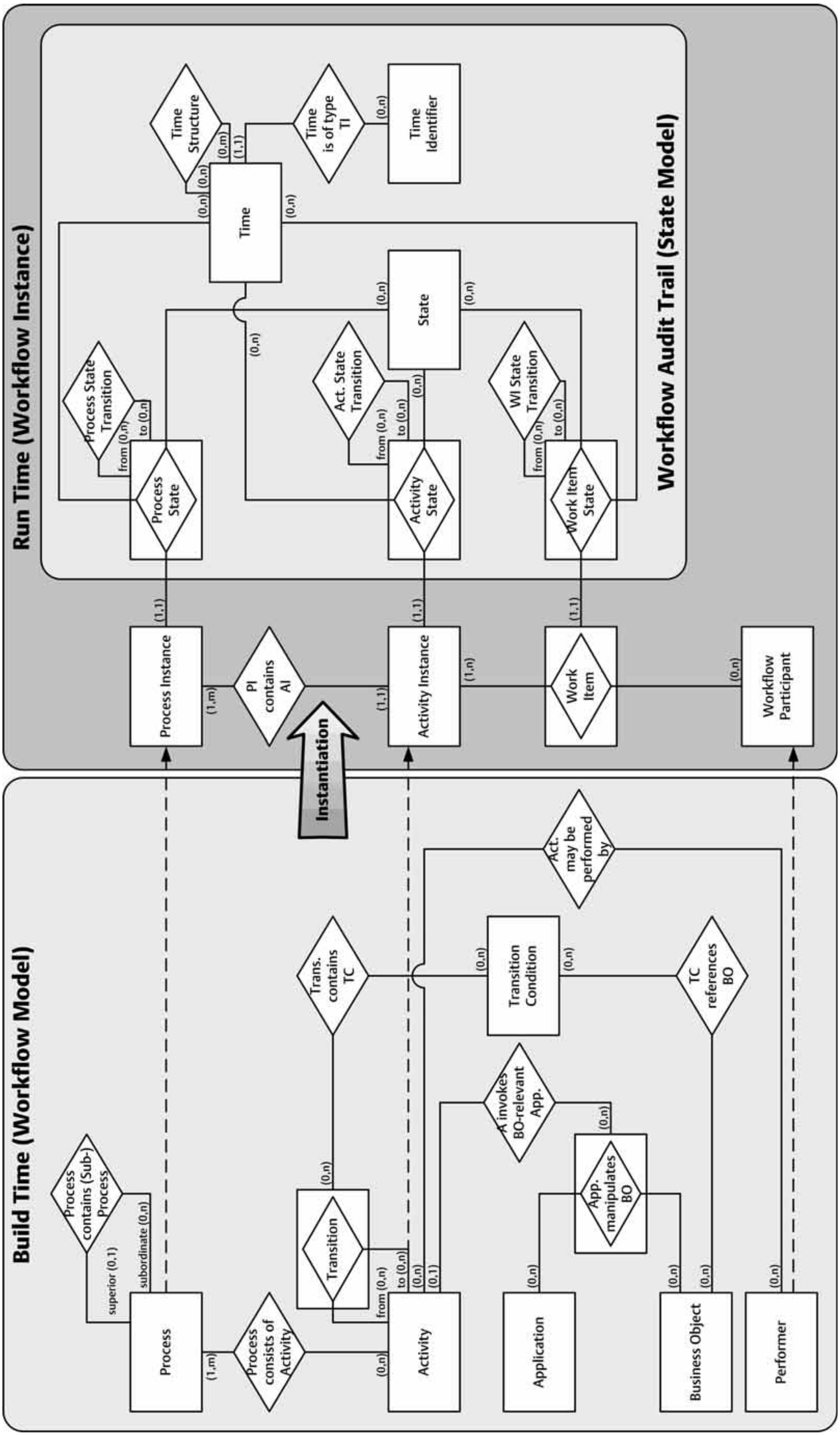

Figure 4-5: Conceptual Workflow Meta Model

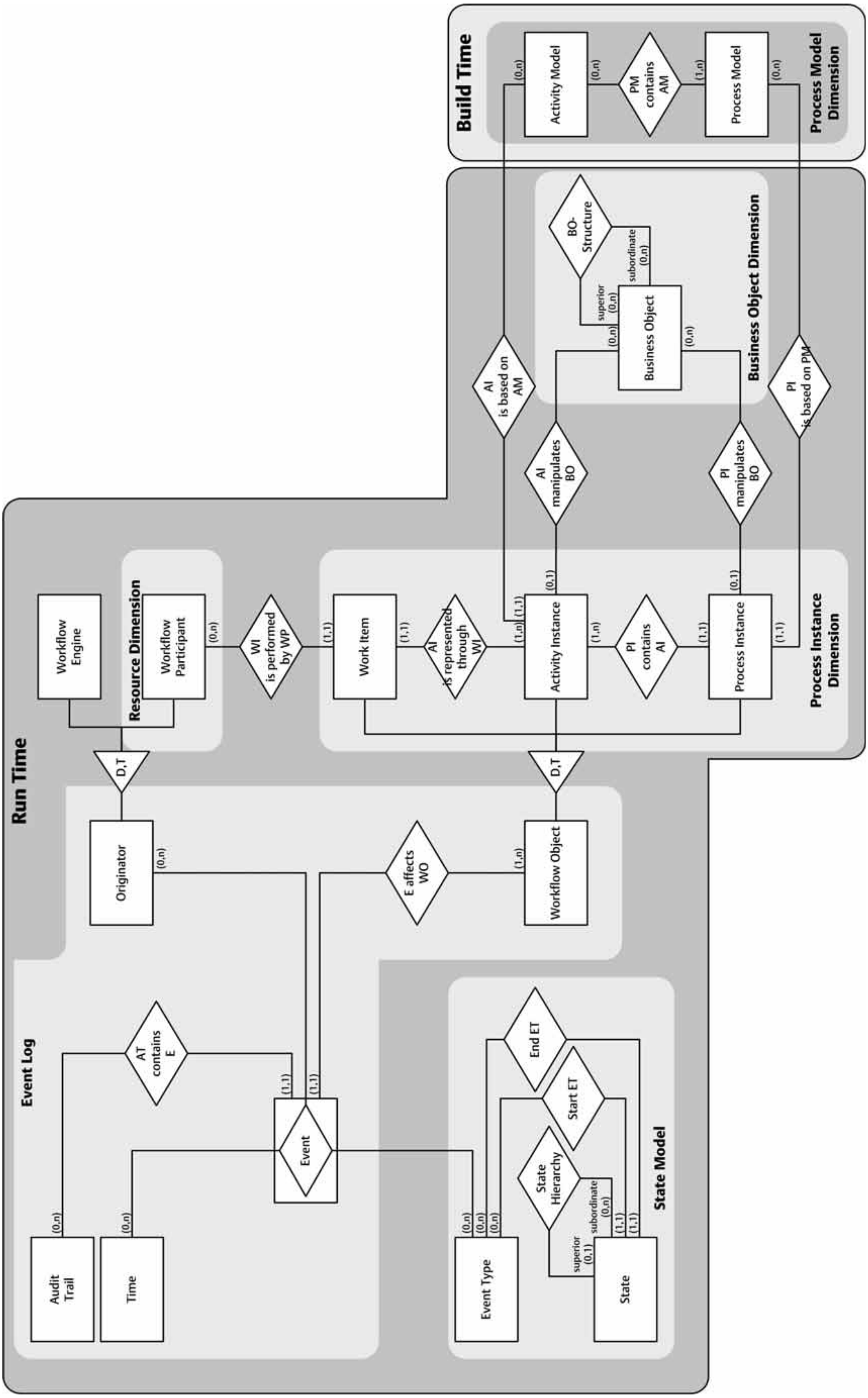

Figure 4-6: Reference Meta Model of Audit Trail Content

which activities were carried out by a specific department, or how many process instances were initiated by a specific work group.

The workflow objects work item, activity instance, and process instance form the *process instance dimension*. Within this dimension, audit trail entries can be grouped according to the process hierarchy, i. e., all work items belonging to a specific activity instance, and all activity instances belonging to a specific process instance. Since the instantiation relationships between activity instances and activity models are known, as are those between process instances and process models, audit trail information can be further aggregated to include multiple instances of the same process type.

Both activity instances and process instances may be associated with a *business object*. This business object links the process-focused workflow audit trail with the economically relevant objects manipulated during the execution of activity and process instances. The recursive business object structure allows for the composition of complex business objects from elementary business objects. This feature can be used to integrate otherwise unrelated business objects that are manipulated during the enactment of different activity instances into a more complex process object.

Database Structure

In order to implement the audit trail structure represented by the meta model, a corresponding database table structure is needed. Figure 4-7 gives an overview of the audit trail table structure. The top part of the diagram contains the tables filled during the build time phase of the workflow application. They contain information about the activity and process structure. Below these tables, the work item, activity instance, and process instance tables are shown, which are filled by the workflow engine at run time. The lower half of figure 4-7 shows the core audit trail table structure, the audit trail table being the central access point for audit trail analysis.

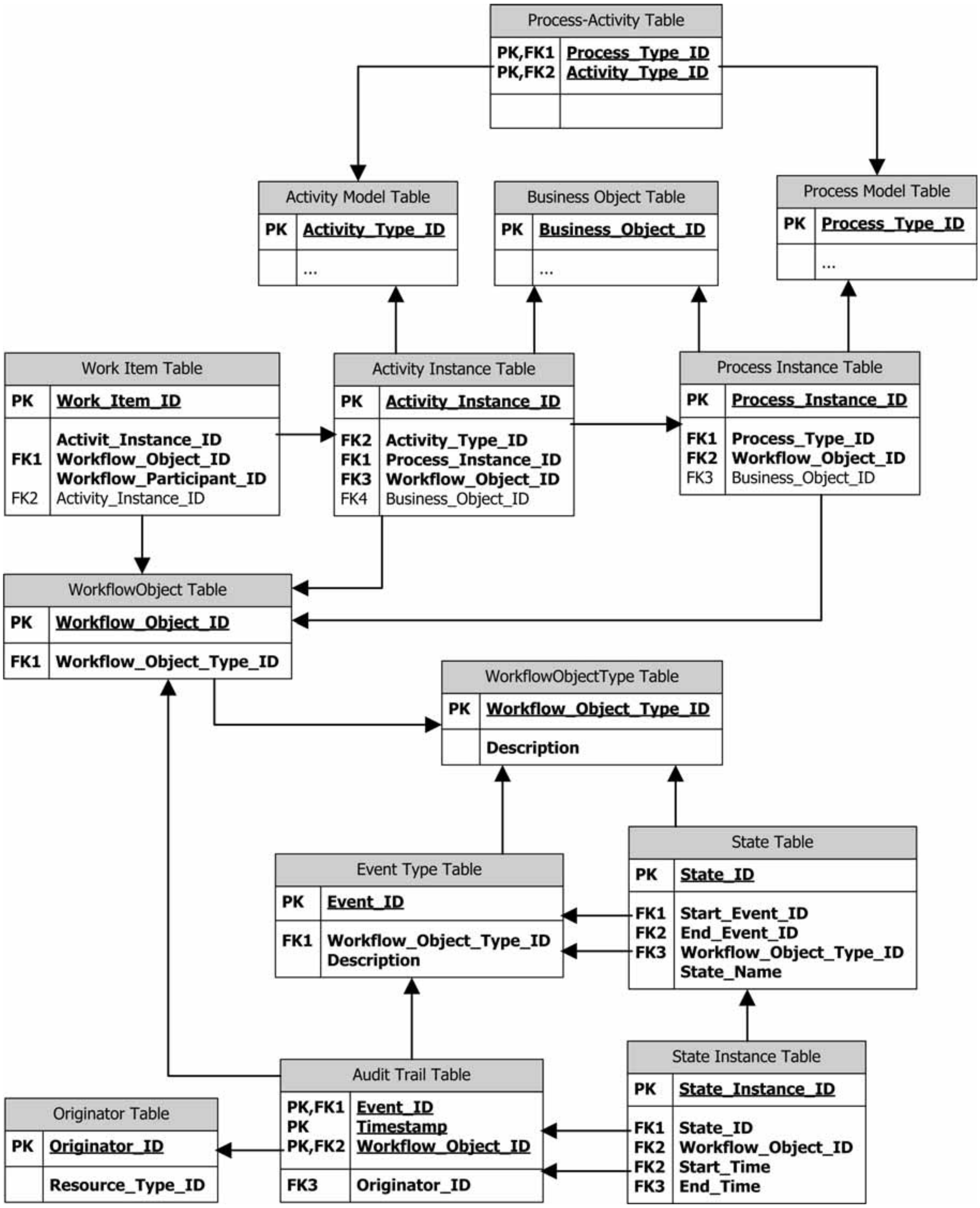

Figure 4-7: Audit Trail Table Structure

4.3 A Conceptual Framework for Process Controlling

4.3.1 A Taxonomy of Audit Trail Information

Information recorded in the workflow audit trail can be analyzed in different ways, depending on the organizational function and information requirements of the recipient. Figure 4-8 shows a classification of different analysis dimensions for audit trail information. The dimensions can be classified into attributes that relate to the way how audit trail information is presented to the recipient, and the content of the information presented to the recipient.

Attribute	Possible Values					Group
Focus	Technical Information	Business Information				Presentation
Presentation	Active	Passive				Presentation
Timeframe	Running Processes	Completed Processes				Presentation
Aggregation	Single Instance	Multiple Instances				Presentation
Data Scope	Process	Process + Business Objects	Enterprise			Information
Object	Event	Activity	Process	Resource	Business Object	Information
Process Scope	Activity	Segment	Process	Process Chain		Information

Source: Extended from Blum (2002), p. 18.

Figure 4-8: Analysis Dimensions of Audit Trail Information

Presentation of Information

Focus

The focus of audit trail analysis can be either *business-oriented* or *technology-oriented*. This orientation is determined by the role of the process analyst and by goals supported by the results of the process analysis. A technology-oriented analysis relates to information that reflects the performance of the workflow management application, such as response times, number of concurrently logged in users, or system behavior at different work loads. In addition, technology-oriented analyses can yield information about software components invoked during workflow execution. For example, the analysis of concurrent invocations of the same application program can be used to determine the number of licenses required to match the current software usage patterns.

Presentation

Audit trail information may be presented *actively* by the workflow management system or process controlling system, if alert functions are implemented. An active presentation of audit trail information is also required, if this information represents input data for other automated processes, e. g., the daily recurring generation of a process report. A *passive* presentation of audit trail information can be found, if the user has to select the information he or she is interested in, and has to initiate the presentation of the information manually.

Timeframe

Audit trail information may either relate to processes that have been *completed* (aborted, or terminated, respectively), or relate to processes that are currently *active* in the workflow management system. The analysis of active processes can be used for predictive purposes, e. g., to determine the estimated time of completion of a process instance, or to determine the current workload of a group of process participants.[601] Audit trail information relating to completed processes are typically analyzed at an aggregate level, in order to identify generalizable properties of a particular process type.

Aggregation

Audit trail data can either be analyzed on the *instance level*, e. g. if for a particular process instance a proof of execution is required, or at the type or *model level*, e. g., if trends of process metrics over time are of interest. For process controlling purposes, audit trail information is typically aggregated over several instances of the same workflow model. If process models are modified, the process analyst needs to maintain information as to which versions of a process model are compatible for analysis, i. e., the process instances of which process model versions can be combined and/or aggregated.

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601. Compare, e. g., Panagos, Rabinovich (1997), who use audit trail information to raise preemptive escalations, if the current workflow instance might exceed the maximum permitted turnaround time.

The opportunity to model and change processes using a workflow management system is significantly easier than the adjustment of hard-coded process logic in application systems. Therefore, over time, enterprises using workflow applications will adjust these processes to match their changing environment. The change of the process structure, e. g., the replacement of an activity with another, results in a change of the audit trail data during process enactment. If an analysis is to be performed across a collection of process instances, in many cases only those instances will be relevant whose execution path is identical, i. e., those instances where the set of activity instances is identical, and that refer to the same activity model (version) at the type level. Therefore, it is vital for the validity of the process warehouse information to record the underlying workflow model variant for every workflow instance.

Information Content

Data Scope

The scope of data analysis can be restricted to *process information*, include associated *business objects*, or consider the *entire enterprise* as an analysis domain. In the first case, the information stored in the audit trail provides all necessary information to compute frequencies, time-related ratios, and other information at the process and activity levels. The integration of business object information requires the linking of activity instance information with business object identifiers, as it has been proposed in the audit trail reference meta model. This is only possible if key attributes of the business object(s) are accessible for the workflow engine as workflow-relevant data. Therefore, process designers have to consider process controlling requirements already in the conceptual design phase of a workflow application.

If the analysis of enterprise level information is desired, it may be necessary to compare process performance metrics across different departments. In this case it is useful to provide an enterprise framework of related processes. In the example of a divisional organization, a process analyst may wish to compare purchasing processes from different departments.

Object

The central object for process analysis can be either an *event, activity, process, resource*, or the associated *business object*. Analysis at the event level may be used to identify processes with irregular operation. For instance, an analysis of all “abort process” events will result in a list of all processes that did not complete successfully. The activity level yields information about the efficiency of task fulfilment, and may be used to compare similar activities in different processes. If processes are the central object of analysis, path analyses may provide insight about the distribution of business cases and resulting resource requirements. Analysis at the resource level aims at identifying organizational ratios or developments, such as learning curves for the execution of a single activity over time, or the productivity of a work group.[602] The business object focus allows for a grouping of processes in accordance with the process object. This can be useful to analyze the performance of processes with regard to certain process object attributes. For instance, an analyst could compare the turnaround time of order processing workflow instances for customers from Rhode Island with those instances for customers from New Jersey.

Process Scope

The process scope describes the part of a particular process model analyzed by the process controller. The finest level of granularity within this category is the analysis at the activity level. The analysis of a larger part of a process provides information about *process segments*. The study of the audit trail at this level may be useful to determine the behavior of alternative process paths, or alternative activity configurations. Analyzing the entire process corresponds with the process object focus of the previously discussed category. Finally, a process analyst may be interested in the behavior of an entire process chain, which may be confined within the enterprise or stretch across enterprise boundaries to include processes from suppliers and customers (supply chain controlling). The analysis of process chains requires the identification of matching process instances, i. e., since the completion of one process instance triggers the enactment of the next process instance, the audit trail needs to contain information about the global process model, which encloses all partial processes.[603] Figure 4-9 illustrates the reach of different process scopes.

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602. Note that the use of audit trail metrics for the measurement of organizational productivity may be subject to legal restrictions. For instance, German privacy law provides strict rules for the electronic storage and transmission of personal information. In order to satisfy these restrictions, resource information in audit trail data can be locked from access, deleted, or reduced. To reduce resource information it is possible, e. g., to aggregate process performer data to the group level, while individual evaluations are not possible, or to anonymize data by replacing actual values with proxy values. Compare Herrmann, Bayer (1999).

603. The analysis of inter-organizational workflows on the basis of XML messages was analyzed in the context of the AFRICA project at the University of Muenster, for more information compare zur Muehlen, Klein (2000). Web Services Choreography languages that are used to specify cross-organizational processes use the concept of *correlation keys* to identify matching process fragments across different systems and/or business partners.

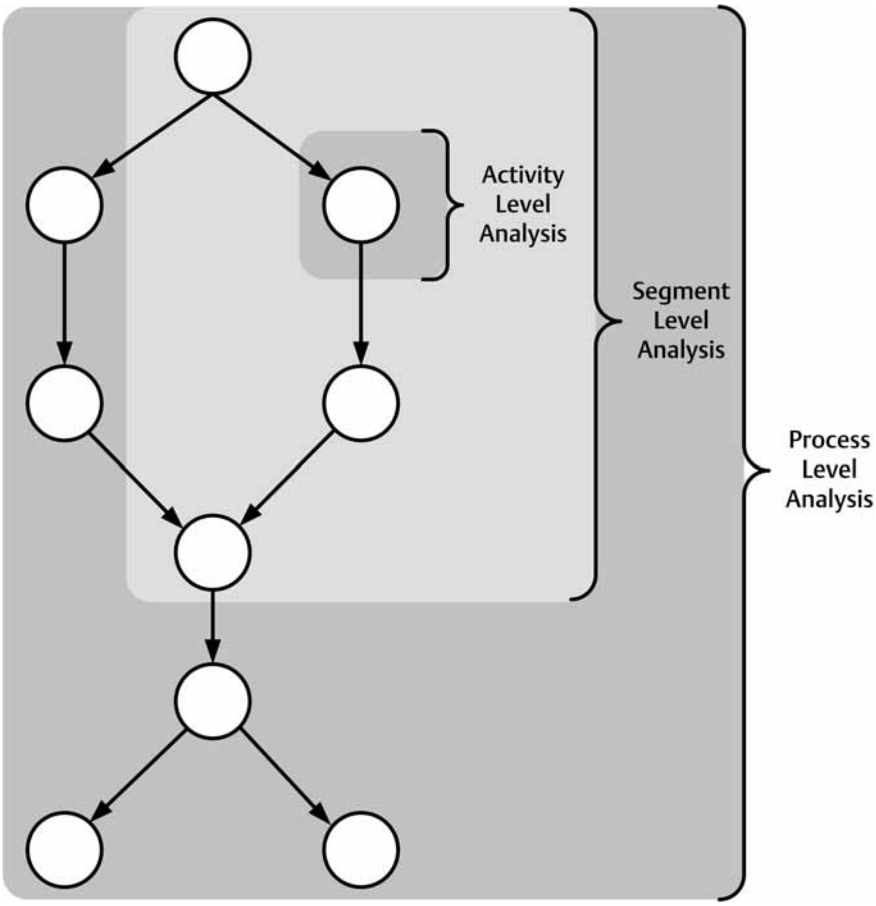

Figure 4-9: Activity, Segment, and Process Level Analysis

4.3.2 Process Monitoring versus Process Controlling

Process Monitoring

Process monitoring deals with the analysis and representation of process instances at run time. Using monitoring information, workflow administrators and process managers can manipulate the behavior of current workflow instances and react to problems that arise during process enactment. Furthermore, process monitoring is used to improve the responsiveness of an organization to customer inquiries. When the current state of a process instance can be determined with ease, customer inquiries such as "Who is handling customer order 4711?" can be answered efficiently. For the individual workflow participant, process monitoring provides the ability to identify those colleagues that worked on a particular case, if there are open issues that need to be resolved. Figure 4-10 shows the monitoring of an online order while it is being processed by the vendor.

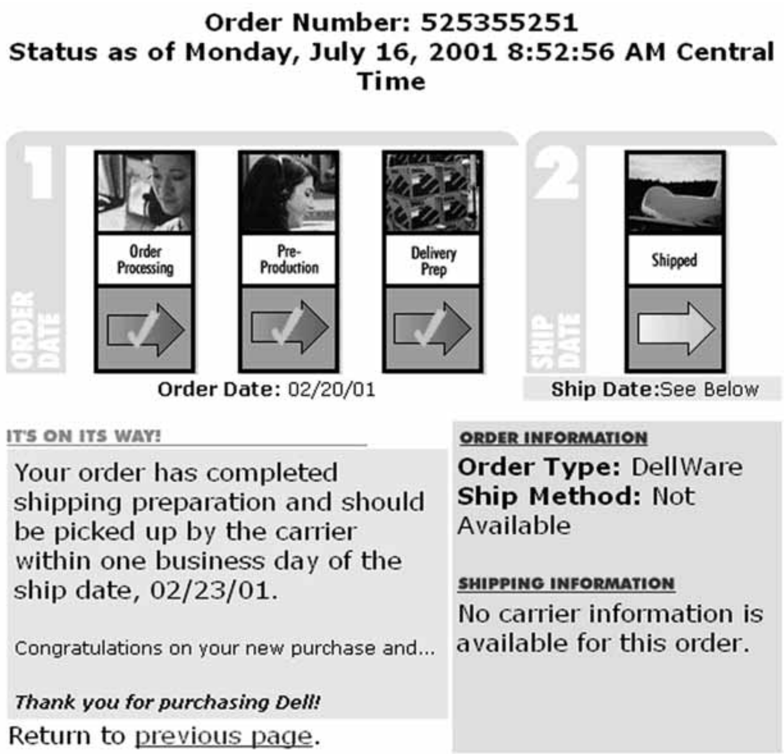

Figure 4-10: Monitoring of an E-Commerce Order

Process monitoring beyond single process instances can be used to predict staffing requirements. If the average processing times of activities allow for a forecasting of pending activity instances in the near future, the number of active process instances as well as the current activity instances allow the short-term prediction of staffing requirements. Combined with the ability of workflow management systems to prioritize work items according to the case attributes and the age of the case (i. e., the idle time of a pending case), process monitoring can help companies maintain a consistent level of cycle times even during seasons with high workloads.

The importance of workload transparency can be illustrated using the case of a German insurance company. Due to a proposed change in tax legislature, life insurances policies were subject to additional taxation if the policy was signed on or after January 1st, 2000. This announcement led to a fourfold increase in life insurance applications during the second half of 1999. The staff at the life insurance department worked overtime to handle the unusual amount of applications, neglecting all other cases that were not new applications. As a result the structure and age of the remaining cases was unknown and customers complained about the long time it took the insurance to get back to them with regard to their inquiries. This situation could have been avoided if a workflow management system had tracked of all cases and prioritized those cases that were older than a certain threshold.

Under certain conditions it is desirable not to expose the detailed process structure to the party monitoring a certain process instance. An example is the presentation of workflow data to process participants outside of the organization where the process instance is executed in, e. g., customers, suppliers, or government agencies. Figure 4-10 shows the web display of an ordering process at an e-commerce web site. Even though the internal processes are much more complex, only four steps are displayed to the user. This *business state* differs from the actual *process state* in the way that it is an abstracted state model of the underlying process state model (NAEF et al. call these state models shadow processes[604]). Figure 4-11 shows an example of the abstraction level between the actual process state and a business state.

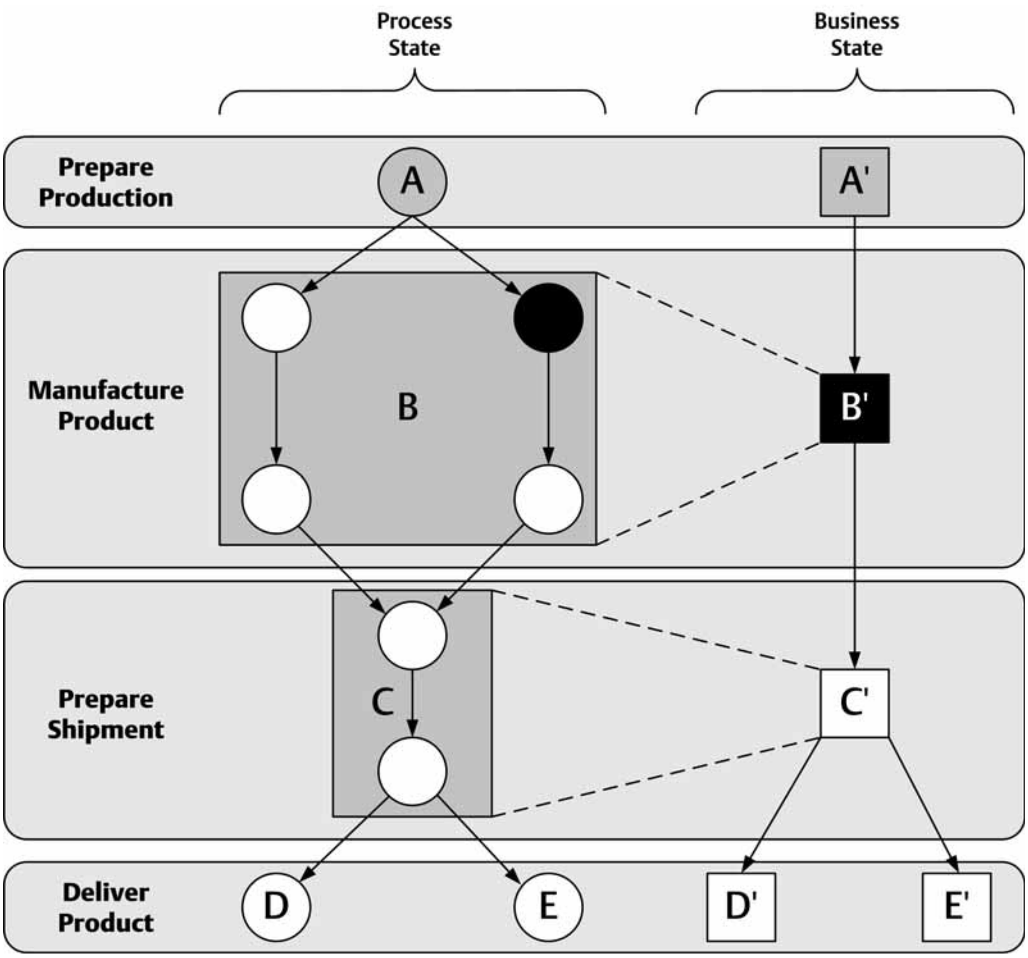

Figure 4-11: Process State and Business State

The four activities in section B and the two activities in section C are combined into the single business states B’ and C’, respectively, whereas the activities A, D, and E appear at the same level of granularity in the business state model. In the (internal) process instance, activity A has been completed and one activity of segment B is currently active. The corresponding busi-

604. Refer to Naef, Schuler, Schuldt (2001), p. 90f.

ness state model shows state B' as active, abstracting from the underlying details of the "Manufacture Product" process segment. In the simplified example, the business state model can only contain the same number of states or fewer states than the process state model (n:1 relationship), since it is derived from the workflow states exclusively. If context data is taken into account - such as the values of certain process relevant variables, the coarse states of the business state model may be refined into sub-states.

Besides organizational process monitoring, workflow management systems typically provide facilities for technical monitoring. Technical process monitoring deals with the supervision of parameters such as response times, system load, and the like. With regard to technical monitoring, workflow management systems do not differ from complex application systems that are managed through commercial packages such as TIVOLI[605] or CANDLE[606]. Figure 4-12 shows a screenshot of the technical monitoring facility of the Carnot Process Engine. Besides the current numbers of active users, processes, and activities, the system also displays the number of pending processes and activities, i. e., those processes and activities that have been accepted by a user but that have not been completely processed.

Process Controlling

Process controlling deals with the ex-post analysis of process instance audit trail data. Here the single process instances are aggregated according to different evaluation dimensions schemes. Process controlling is useful for the detection of long-term developments in process enactment and the review of already existing workflow implementations. In order to identify deviations in process execution, audit trail data is often compared to target data which is derived from corresponding business process models. The goal of workflow-based process controlling is the improvement of future process enactment, thus its effects are more long-lasting than the results of process monitoring.

Whereas the target audience for process monitoring data consists mainly of administrative IT personnel (for technical information) and workflow participants (for organizational information), process controlling data is mainly used for enterprise controlling purposes. An isolated analysis of audit trail data provides information about the temporal aspects of process execution. In addition, information about resource utilization on the process and activity level can be derived. However, information about the business context of a particular process cannot be answered by looking at audit trail data

605. See the Tivoli Corporation Homepage: www.tivoli.com.
606. See the Candle Corporation Homepage: www.candle.com.

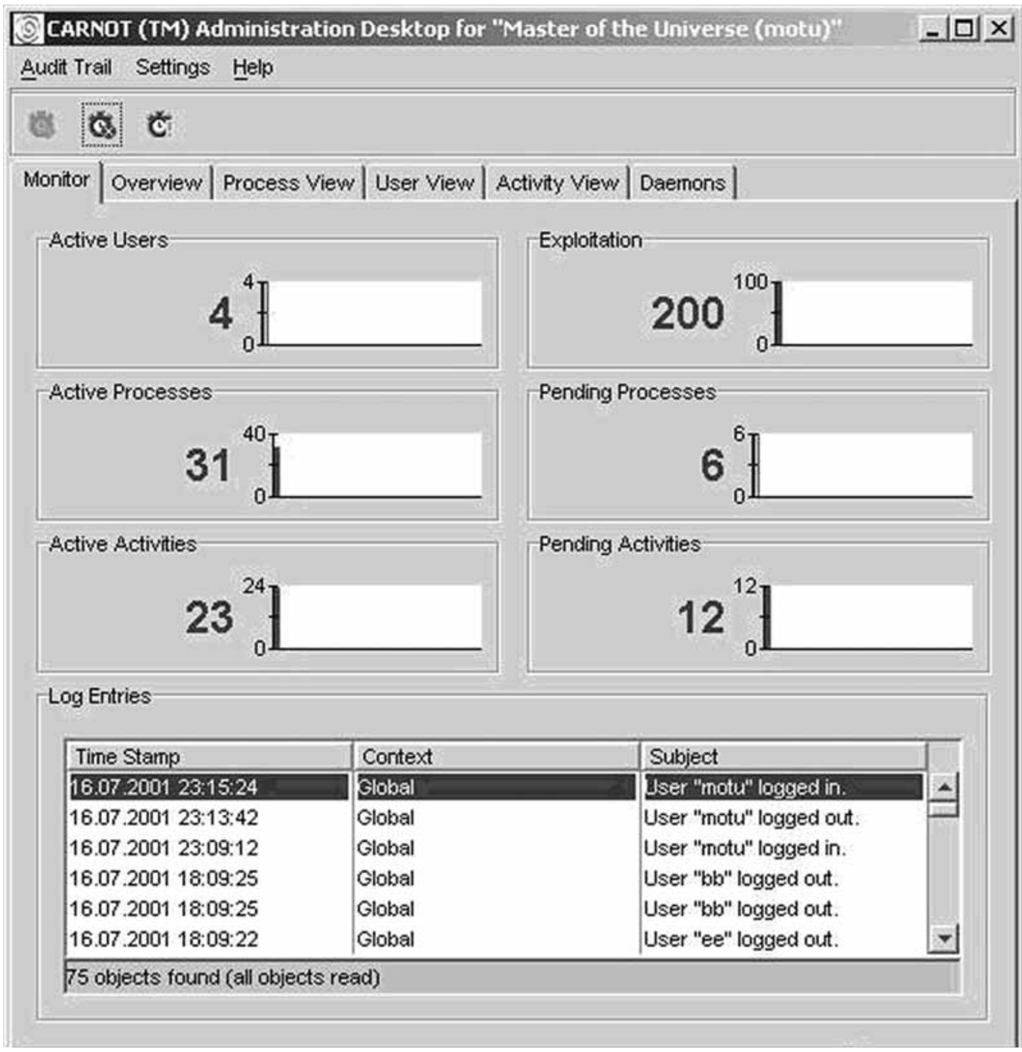

Figure 4-12: Technical Monitoring Facility

alone. This is due to the fact that the audit trail of most workflow management systems does not contain application data that is processed in workflow instances.

4.3.3 Information Requirements and Information Supply

Information requirements of decision makers at different levels of the corporate hierarchy are not uniform. They depend on the management objective pursued by the individual manager, the method chosen to analyze the current situation, and the organizational measure used to realize the management objective.

Management-driven Information Requirements

Figure 4-13 shows the relationship between managerial objectives and available information sources as a meta model. Managerial tasks of the enterprise are distributed among different *management levels*, which are

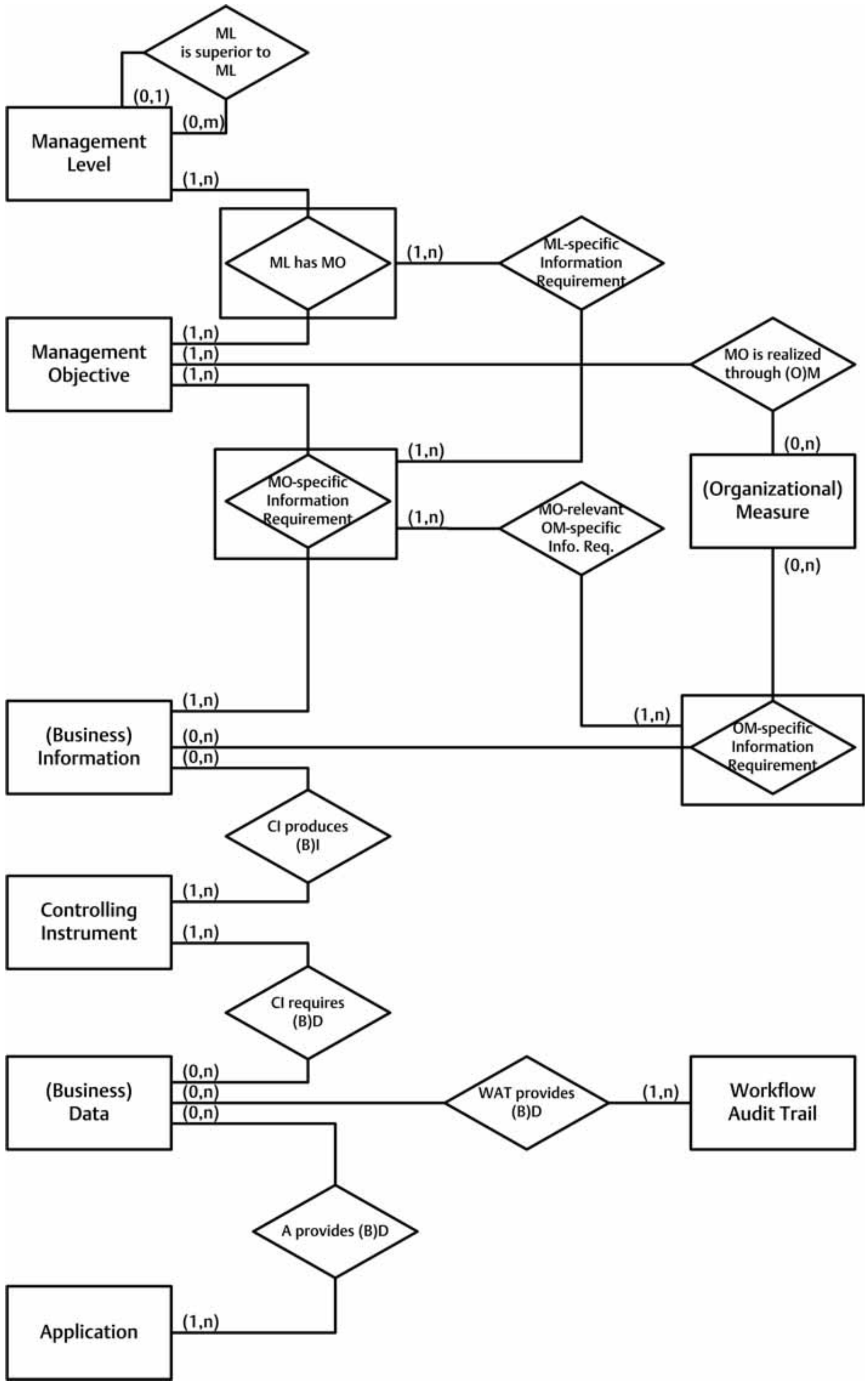

Figure 4-13: Management Levels and Information Sources

arranged in a hierarchy. Each management level has at least one *management objective*, i. e., the set of corporate goals that the specific management level has to achieve. In order to realize these objectives, one or more *organizational measures* can be implemented. In order to decide which measure is suitable for a given situation, a manager requires information about the situation of the company, denoted as *business information*. The sum of all management objective-specific information requirements with all management objectives for a particular management level determine the *management-level-specific information requirements*. For the implementation of organizational measures, managers need information to determine the degree to which individual organizational measures have been realized. Combined with the information demand specific to a manager's objectives we can determine the amount and type of information required. This can provide an indication of the degree to which an organizational measure supports a management objective.[607]

Technology-driven Information Supply

Company-specific business information that is required by managers to perform their decision processes is generated by the operative system of the enterprise. Functional *application systems* and process-oriented workflow *audit trails* provide a basic set of *business data* for analysis purposes. This data is integrated, transformed and analyzed through different *controlling instruments*. The result of this transformation is the set of business information available for managerial purposes.

4.3.4 Integration of Audit Trail Data with other Data Sources

From an enterprise controlling perspective, workflow audit trail data is one of several information sources and needs to be integrated into a common repository for evaluation purposes. Examples of other information sources that include in such a repository include financial statements from an accounting system or log files from a transaction processing system. In order to enhance the business value of audit trail data, it needs to be integrated with such external data sources in order to enable the analysis of processes using attributes that are not part of the workflow audit trail.

Data warehouses are a common repository for this kind of data, and elaborate on-line analytic processing tools exist that support the controlling recipients during the evaluation of information stored in a data warehouse. INMON defines a data warehouse as the subject-oriented, integrated, nonvolatile and time-variant collection of data in support of manager's decisions.[608]

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607. An example for an organizational measure is the restructuring of a department and the creation of teams-oriented work places instead of individual work places. If the management objective is to increase the resource efficiency, the success of the organizational measure could be assessed by examining the staff productivity before and after the restructuring. Measuring the employee satisfaction may also yield information about the success of the organizational measure, but does not relate to the original goal, since employee satisfaction contributes to the goal of motivation efficiency, but not necessarily resource efficiency.

608. Compare Inmon (1996), p. 33; Inmon, Imhoff, Sousa (2001), p. 8.

INMON relates the *subject-orientation* of a data warehouse to the design of data structures for evaluation purposes, which are modeled after the information requirements of decision makers. BECKER argues that the basic data model of a data warehouse has to be designed independent of evaluation purposes, since the future information requirements are hard to predict.[609] This argument is reflected in RIEBEL'S approach to cost accounting, where he separates the purpose-independent computation of basic ratios, and the subsequent purpose-oriented computation of evaluations.[610] The practice of data warehouse design supports the latter argument. The central data repository is enhanced by subject-specific data marts, which contain a purpose-oriented selection of the main data warehouse data.[611]

The *integration* aspect of data warehouses refers to the consistent naming of variables, encoding of attributes, and adjustment of different measurements used by different operative information systems. This integration is typically achieved through the implementation of an extraction, transformation, and loading (ETL) layer, which offers access to different operational data sources, and provides functionality to cleanse, map, and convert the contents of these data sources into a consistent repository.

Data in the data warehouse is not subject to *changes*, as opposed to data in operative transaction processing systems, since analytical queries on the data warehouse are read-only operations. For this reason, the data structure of a data warehouse needs to be optimized for this type of operation, and may differ from the data structure of operative data stores.

The aspect of *time-variance* relates to the fact that a snapshot of the operative data stores at a specified point in time is transferred to the data warehouse and marked with a timestamp.[612] If new data is transferred to the data warehouse, existing data is not removed but remains available, and the newly transferred snapshot is marked with a new timestamp. This enables the analysis of data changes over a longer period of time.

Due to the popularity of data warehouses as a foundation of the corporate management information system infrastructure, the integration of workflow audit trail data into existing data warehouses provides the opportunity of enhancing existing controlling infrastructures with the ability to

609. Compare Becker (2002).
610. Compare Riebel (1994).
611. Inmon, Imhoff, Sousa (2001), p. 8, define a data mart as "a customized subset of data from the data warehouse tailored to support the specified analytical requirements of a given business unit."
612. Compare Holten (1999), p. 41.

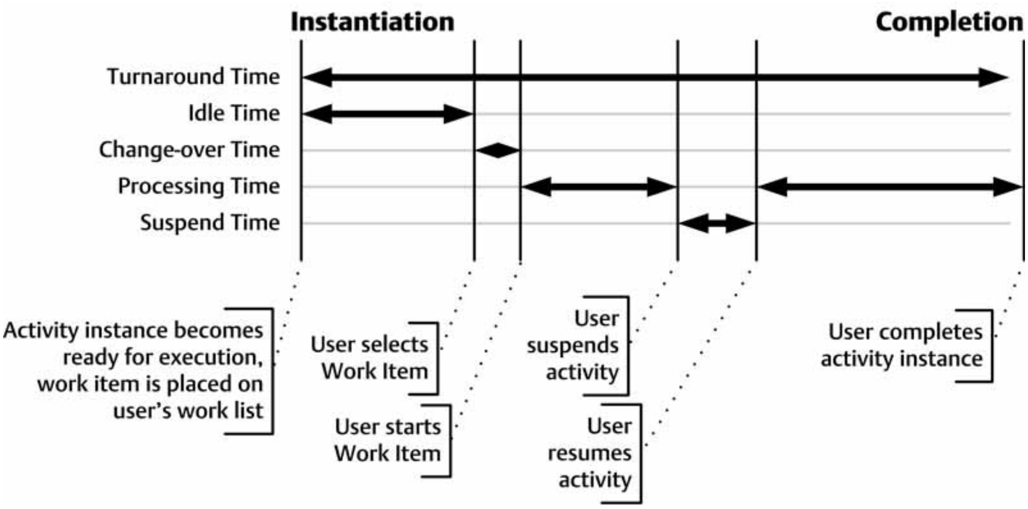
analyze the business process perspective of an enterprise. This task is non-trivial and we discuss its implications in the following section.

Extraction, Transformation and Loading

During the extraction, transformation, and loading phase of data warehouse development, source data is converted into a format that fits the overall data warehouse schema. Depending on the format of existing audit trail logs, which could exist in form of database records or flat file structures, an appropriate import mechanism needs to be deployed. Using a transformation algorithm, the proprietary schema of the audit trail data has to be converted into the data base schema of the data warehouse. If several workflow management systems are used within the enterprise, the individual audit trail schemas have to be converted into a consolidated schema that is suitable for the analytical purposes of the data warehouse.

Data Mart Structures for Audit Trail Information

The content of the workflow audit trail is characterized by its detailed notion of time. In the reference data model, this is one identifying element of the triple relationship *time - workflow object - event type*, which defines the core of the workflow audit trail. For this reason, audit trail data is naturally suitable for a variety of temporal analyses.[613] Figure 4-14 illustrates the relevant temporal aspects using the example of an activity instance.



Source: Compare Rieke (2002), p. 63.

Figure 4-14: Relevant Temporal Aspects for Workflow Analysis

613. The importance of time-based analyses is noted e. g. by Karlof, Ostblom (1993), p. 56: "Time [...] is an excellent unit for measuring the performance of an organization. Short throughput times contribute to customer-perceived quality and most of all to productivity."

Since the workflow audit trail provides timestamps, but not aggregate information about time periods, it is useful to create a time-oriented data mart from raw audit trail data. The data structure of such a data mart contains a central fact table that contains derived information about its activity instances. Figure 4-15 shows the data structure for a time-oriented data mart. The central fact table contains references to the activity model of which the activity instance was derived from, the process instance that formed the context for the activity instance, the resource, i. e., the workflow performer that executed the activity, and the business object that was manipulated in the context of the activity. The facts contained in the fact table are the calculated values for different processing time categories. The calculation of these ratios is a non-trivial task, since each activity instance may have switched an arbitrary number of times between the states idle and processing. As a result, the values for idle time and processing time may be composed of an arbitrary number of processing time fractions and suspend time fractions, respectively.

The references to activities, processes, resources, and business objects opens access to four evaluation dimensions that can be used to formulate queries. For example, the business object perspective may be used to determine those activity instances that exhibit the longest idle time for a specific type of business object. The result of this evaluation may give an indication about popular and unpopular business cases, if the workload for the individual business cases is similar. The resource dimension may be used to determine the learning curve of an organizational unit for the processing of a specific activity. If the processing times of activity instances continuously decrease, the presence of certain learning effects can be assumed.,

In addition to time-oriented analyses of workflow audit trail data, frequency-oriented analyses can be applied to workflow audit trails as well. A data mart for frequency-oriented analyses contains facts about the availability, start, and completion of activity instances. It facilitates queries such as "How many activity instances of the type *review account overdraft* were performed in the last three months?"

As stated in figure 4-8, the analysis dimensions for audit trail information may select activities as well as process segments as the central object of analysis. Theoretically, an activity-centered data mart can be used to compute process-specific ratios that relate to the parent process of an activity. This can be achieved through a traversal along the process dimension, which yields the process instance related to the activity instance in the fact table. Ultimately, the originating process model can be determined as well. In order to allow meaningful analyses, all activity instances from each process

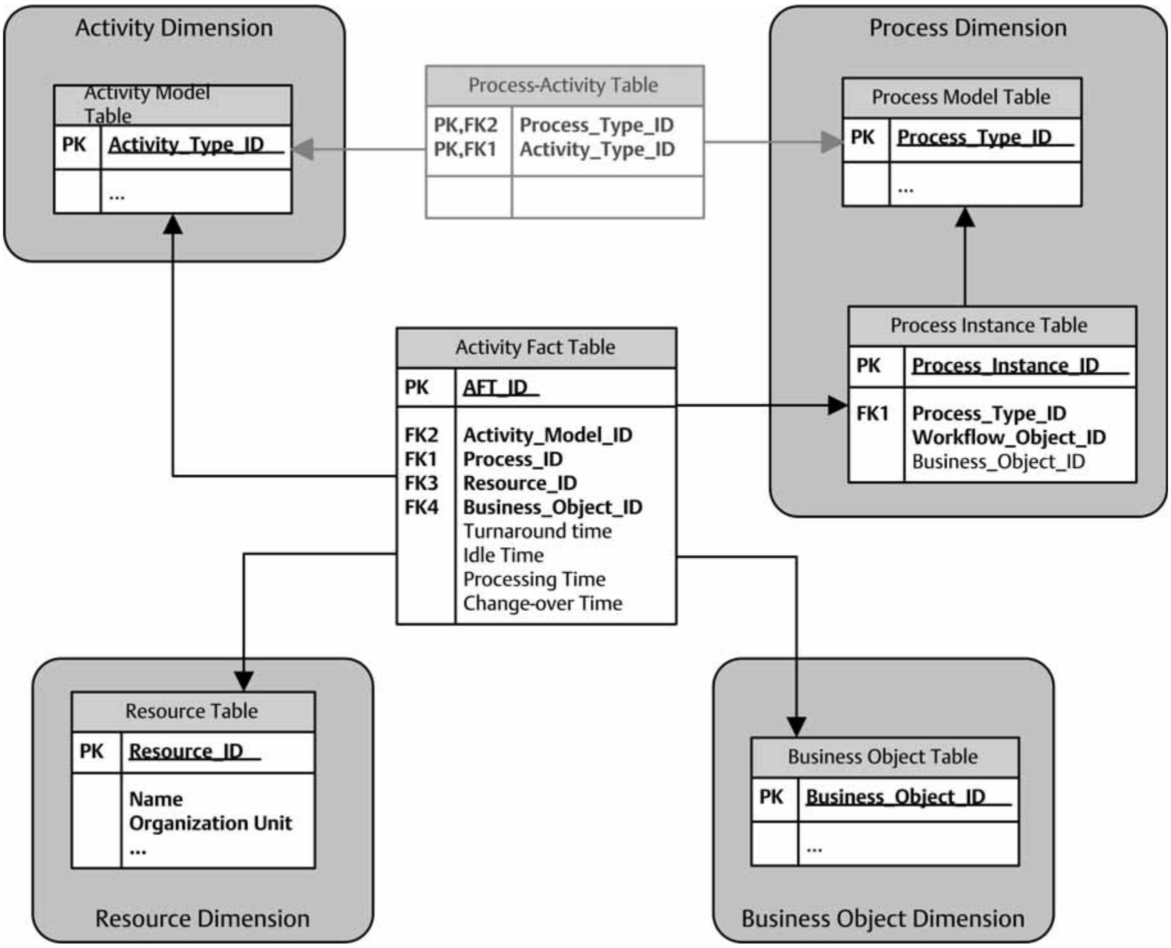


Figure 4-15: Time-oriented Activity Data Mart

instance would need to be identified and their atomic facts would need to be integrated into the evaluation. Since such an operation has a significant negative impact on the performance of process-related queries, it is advisable to create separate data marts for the execution of process- and activity-related queries.

Synchronization of Business Objects and Workflow Data

The audit trail format of some commercial workflow management systems does not contain references to the business object that has been manipulated in a workflow instance. Still, meaningful evaluations in a business context almost always require the workflow audit data to be linked to some business object information, such as the customer account involved, or the merchandise handled during the process. In our previous research prototype PISA we manually added an activity to the workflow model that created a database record containing the ID of the process instance and the identifier of the business object that would later be manipulated by the derived workflow instance. This artificial integration of workflow and business data enables the navigation from a particular process instance to the business context and allows for the application of high-level evaluation methods. Nevertheless, the integration of audit trail information with business object information can create a number of problems for the data warehouse designer:

- *Not every workflow context is a business object.* If a workflow instance uses data from different application systems, an artificial wrapper for this particular data set has to be created for every workflow instance in order to make this data set accessible through a unified business object ID (BOID). While object-oriented workflow management systems (e. g., those running inside a java-based application server) provide native support for this encapsulation concept, most stand-alone workflow systems are designed to work with different applications without an additional data wrapper.
- *Business data is subject to side-effects.* The notion of application data was introduced by the WfMC to make sure that mission critical data was not locked from use while being used by a potentially long-running workflow instance. Reverting this view, application data can be manipulated by applications outside of the workflow context at any time. If audit trail data is transferred through a batch procedure once a day, intermediate changes to the business object data are invisible to the data warehouse. To avoid this problem, business data would need to be transferred to the data warehouse as soon as the workflow instance treating this business object is finished. For performance reasons, this may not always be feasible.

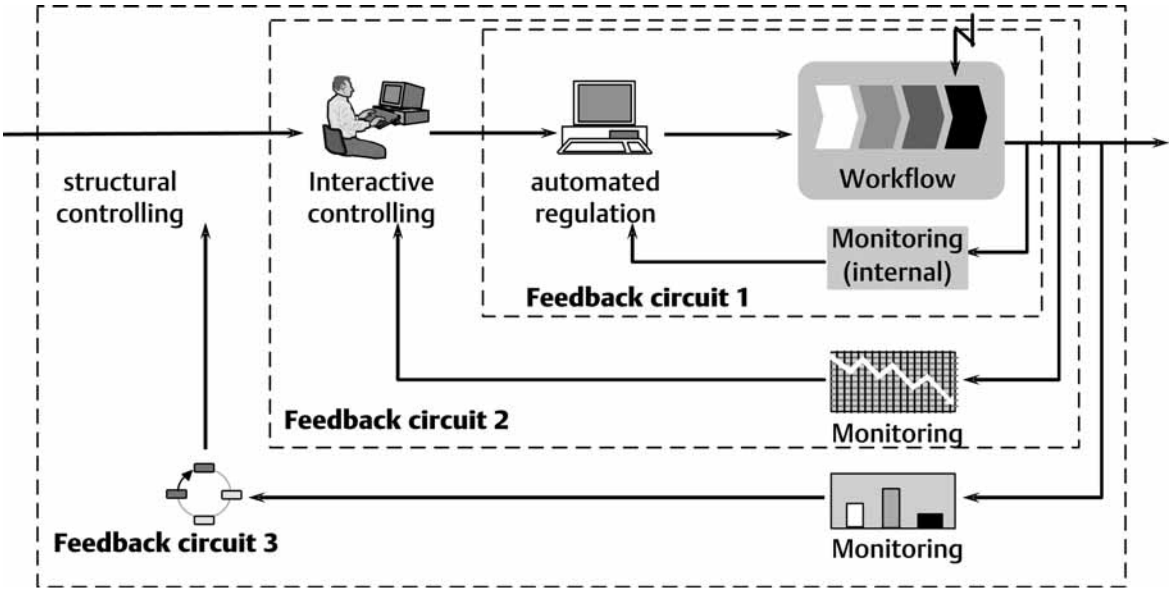
4.4 A Cybernetic Model for Process Controlling

In the previous section we have discussed the data offered by a workflow audit trail for analytical purposes, evaluation possibilities for this kind of data, and strategies for the technical integration of the resulting information in the corporate controlling infrastructure. In the following section we discuss the role of workflow-based process controlling in the context of the cybernetic controlling model that was presented in chapter 2.

4.4.1 Cybernetic Business Process Control

The analysis of audit trail data for controlling purposes takes place mainly as ex-post evaluation, since data is only made available after the associated processing has taken place in the workflow system. Workflow-based controlling thus represents a feedback-oriented controlling instrument.

In a study about control cycles for industrial product development processes, v. UTHMANN and TUROWSKI have proposed a hierarchical model of feedback cycles.[614] They describe the role of the workflow management system as the recorder of measurements, and discuss the implementation of control directives at both the automated and the manual level. The innermost feedback cycle describes the automatic regulation of business processes, e. g., if the workflow management system allocates pending work items to different workflow participants depending on their current workload. The second feedback cycle relates to the interactive management of running workflow instances. Monitoring information is provided to human recipients who can actively change parameters of the running process instances. For instance, if the deadline of an activity instance is exceeded, the workflow management system notifies the process manager who in turn reassigns the pending work item to an experienced process participant. The third feedback cycle is used to continuously improve the workflow model. Monitoring information is provided to workflow designers, who adjust the workflow model in a persistent fashion, i. e., the changes to the model affect all future workflow instances derived from this model.[615] Figure 4-16 shows the structure of the hierarchical feedback cycle model.



Source: v. Uthmann, Turowski (1996), p. 15.

Figure 4-16: Business Process Control Cycles

614. Compare v. Uthmann, Turowski (1996).

615. The change of workflow models at run time and the propagation of changes to running workflow instances has been discussed, e. g., by Weske (1999). Marshalling change to running workflow instances requires an evaluation, whether a change would leave these instances in a consistent state and is a non-trivial exercise.

Even though the structure of the hierarchical feedback cycle model addresses the roles of different recipients, it is focused exclusively on the use of workflow information, i. e., it does not explain the role of workflow information at different management levels within the context of other information sources. In addition, the model suggests that changes are always applied to the workflow model or running workflow instances, but not to the surrounding organization or its policies. The system theoretic view of the company shown in figure 2-5 on page 36 illustrates that strategic control does not directly impact the operative processes of the enterprise. Instead strategic control influences the behavior of operative management through the definition of policies and resource contingencies. Operative management in turn evaluates implementation alternatives for the strategic program and chooses an alternative that suits the current state of the operative system best.

Taking these findings into account, we can now rework the feedback model by v. UTHMANN and TUROWSKI, and detail the role of different management layers. Figure 4-17 shows the system of feedback cycles, which is based on the cybernetic feedback model discussed in chapter 2. A workflow management system produces controlling information (i. e., audit trail data), which is fed into three separate controlling units: *Automated feedback*, *operative management and control*, and *strategic management and control*. In the following sections we discuss these controlling units in detail.

4.4.2 Automatic Feedback Cycle

The automatic feedback cycle is confined to the boundaries of the workflow management application itself. Based on formally encoded quality parameters the feedback module analyzes the data supplied by the workflow engine and regulates the execution of running workflow instances. These quality parameters include values such as maximum activity duration, maximum work load for workflow participants, or work distribution strategies. The measures implemented by the feedback unit are restricted to the capacities available to the workflow management system. For example, the feedback unit can reassign a pending work item to a workflow participant different from the original recipient, in order to balance the overall work load, but it cannot create resource capacity, since this parameter is determined at the operative management and control level. While the feedback unit may not perform structural changes to the workflow model, it may manipulate attributes of process and activity models as well as workflow participants. An example for this type of feedback control is the experience-based scheduling of workflow participants.

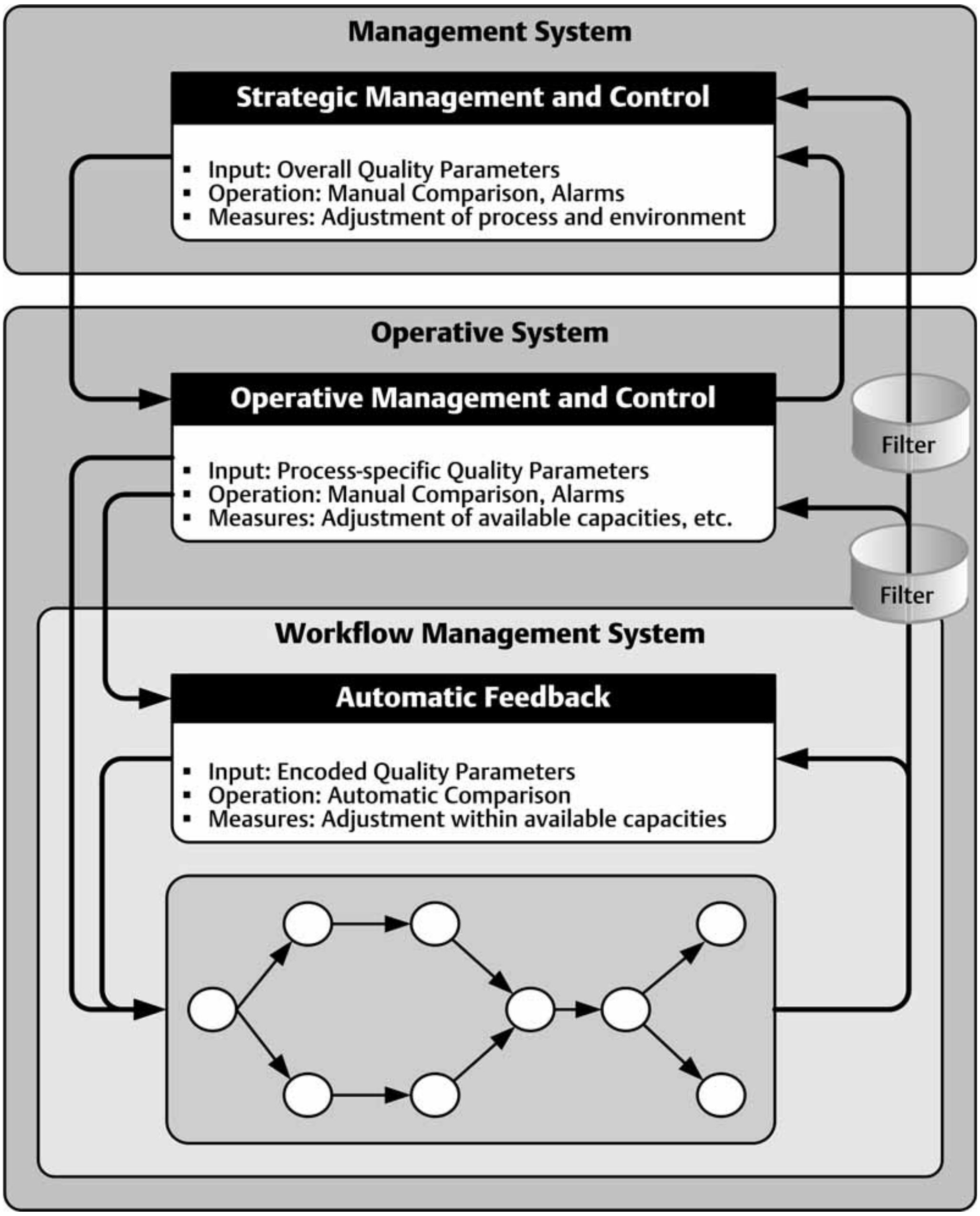


Figure 4-17: Cybernetic Feedback Model of Process Controlling

Example: Experience-based Scheduling based on Audit Trail Data

Workflow audit trail data contains information about the performer of an activity instance. This data can be used to compute a level of experience that is proportional to the number of activity instances performed by a workflow participant, or the activity cycle time for this participant compared to the average completion time across all performers. Using this metric, the dynamic evolution of human resource capabilities can be traced by determining a level of expertise from the analysis of recorded audit trail data.

Even well structured processes, such as those found in so-called production workflow environments, may exhibit a considerable number of exceptions that need to be handled. In the usual case, a workflow administrator or the manager of the current process participant is notified if a workflow or activity instance raises an exception. The importance of efficient exception handling is pointed out by SACHS, who states that the efficiency of work is less dependent on the structure of the workflow, but rather depends on the exception handling capabilities of the resources involved in the process.[616]

Instead of using a hard-coded exception handling scheme, the workflow engine can assign work to a more experienced performer when an exception occurs. This way, line managers are less concerned with troubleshooting activities, such as the reassignment of work items, and can perform activities of higher business value. The economic impact of a qualification-adequate task assignment can be measured using the hedonic wage model developed by SASSONE.[617] The hedonic wage model states that the overall cost of labor increases, if workers perform tasks that lie below their level of qualification and spend less time on tasks they have originally been hired for. Information stored in the workflow audit trail can be used to monitor the value of atomic labor units according to the hedonic wage model, and to adjust the assignment policies accordingly. PISA II and III both implemented an evaluation module for the hedonic wage model.

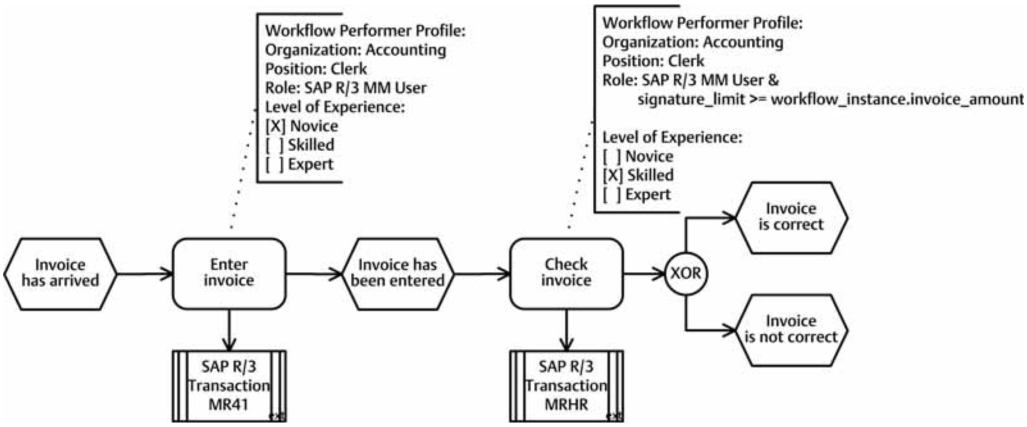


Figure 4-18: Sample Performer Profiles

The use of workflow audit trail data to assess user capabilities can also be used to differentiate resource qualifications, e. g., with regard to processing time or acceptance rate. Depending on the overall priority of a process it might be desirable to assign an activity to the actor with the least average

616. Compare Sachs (1995).
617. Compare Sassone (1986).

processing time for the specific activity at hand. In other cases it may be necessary to minimize the lead time until a work item is processed by a workflow participant. An analysis of the audit trail data can provide the resource management component of the workflow system with relevant information for this decision. An example for resource assignments using the level of experience as an assignment factor is given in figure 4-18.

4.4.3 Operative Management and Control

The operative management and control loop starts with the supply of workflow audit trail data to the operative management and control unit. Since the amount of data required at this level differs from the raw data processed by the feedback unit, filters have to be used which allow the presentation of relevant information objects only. An example for such filtering is the elimination of technical events from the audit trail data stream, such as system recovery messages written by the workflow engine to document the state of the workflow system itself.

The operative management and control loop can be triggered manually, (e. g., if a workflow application is reviewed on a regular basis), or automatically (e. g., if predefined threshold values are exceeded and the workflow system sends an alert message). The capabilities of operative management and control are twofold with regard to changes at the workflow level. On the one hand, parameters of the feedback unit can be controlled through the operative management and control entity (e. g., a different target cycle time for an activity is defined). On the other hand, adjustments at the workflow system level can be performed. These adjustments include the (re-)modeling of processes, changing invoked applications, and changing the organizational structure. Within this portfolio, the operative management and control unit has the capability to adjust resource contingencies available to the workflow engine, which also represent the limits of the measures the automatic feedback unit can implement. In order to fulfil this task successfully, the operative management and control unit requires information about available resource capacities and resource utilization from the workflow management system.

Example: Workflow-driven Activity-based Costing

One suitable evaluation method for this purpose is activity-based costing. According to COOPER and KAPLAN, an activity based costing model is “an economic map of the organization’s expenses and profitability based on organizational activities.”[618]

618. Kaplan, Cooper (1997), p. 79.

Activity-based costing systems address the following questions:[619]

- Which activities are being performed by the organizational resources?
- How much does it cost to perform these activities and the aggregate business processes?
- Why does the organization need to perform activities and business processes?
- What fraction of each activity is required for the organization's products, services, and customers?

The workflow audit trail can provide activity-based costing systems with actual quantities of activity execution, in addition to a qualified list of the resources used to perform these activities. The combination of workflow audit trail data, operative learning and control, financial reporting, and activity-based costing systems supplies members of the operative management and control unit with timely and precise information about resource utilization in their domain of control. This information can be extended with information about the processes and activities these resources have participated in. Figure 4-19 illustrates this combination.

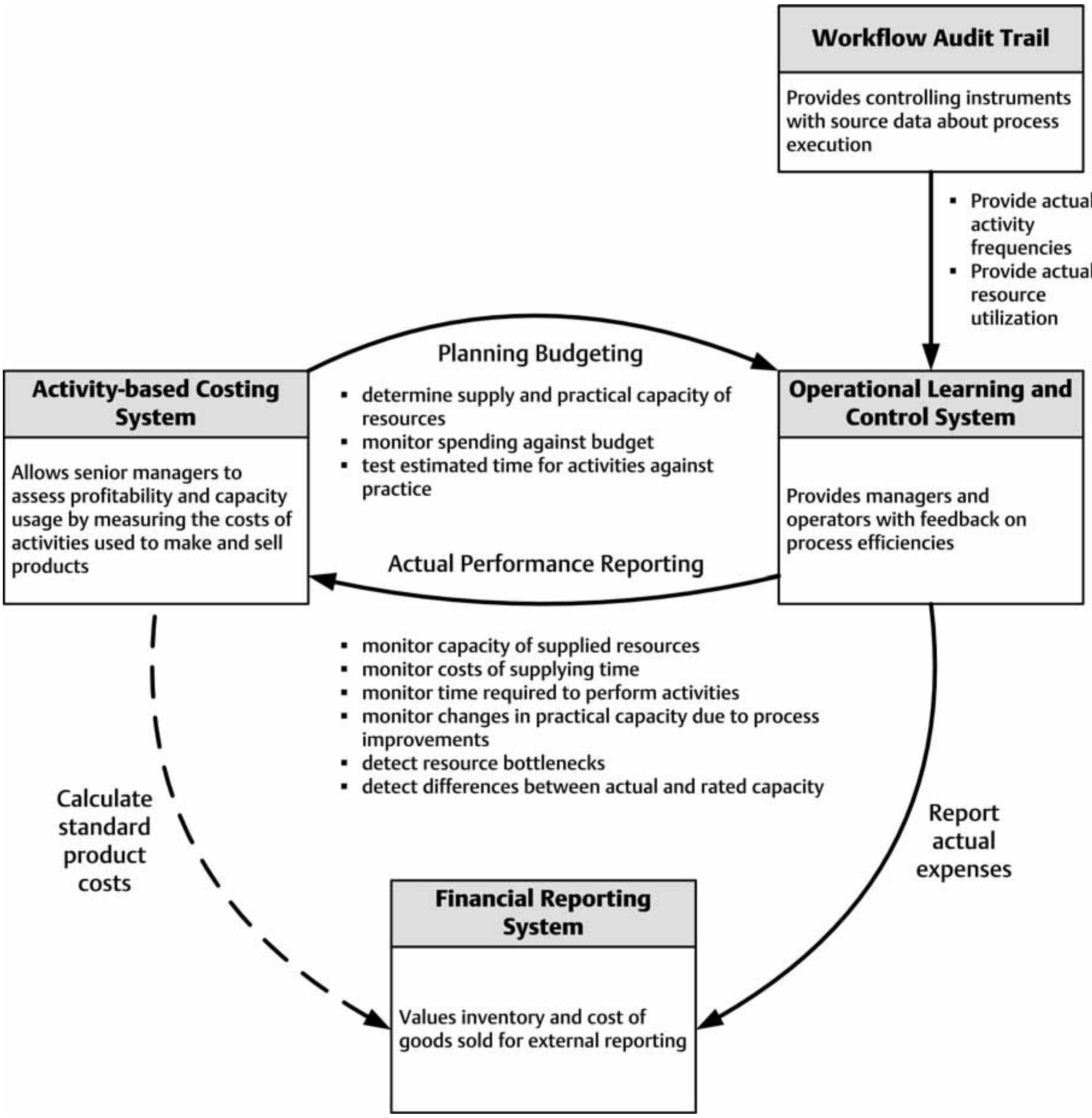
Based on the results of an activity-based costing analysis, managers at the operative level can adjust resource quantities to match the actual resource requirements reported by the workflow-enhanced activity-based costing system. Examples for such adjustments are the hiring of new staff members, the training of staff members to perform different or additional tasks, or the reduction of staff capacity.

4.4.4 Strategic Management and Control

The highest level of feedback control is the strategic management and control feedback cycle. The strategic management and control unit receives select information from the workflow audit trail. For this reason, a second filter on top of the operative management and control filter needs to be implemented at this stage. Additional information is delivered from the operative management and control unit. This level reports to the strategic management and control unit if the second-level feedback cycle escalates, e. g., if adjustments of resource capacities don't have the desired or predicted effect on operative process performance.

Strategic management and control determines the framework for the activities at the operative level and communicates these guidelines to the

619. Compare Cooper, Kaplan (1992); Kaplan, Cooper (1997); Cooper, Kaplan (1998).



Source: Compare Cooper, Kaplan (1998), p. 115.

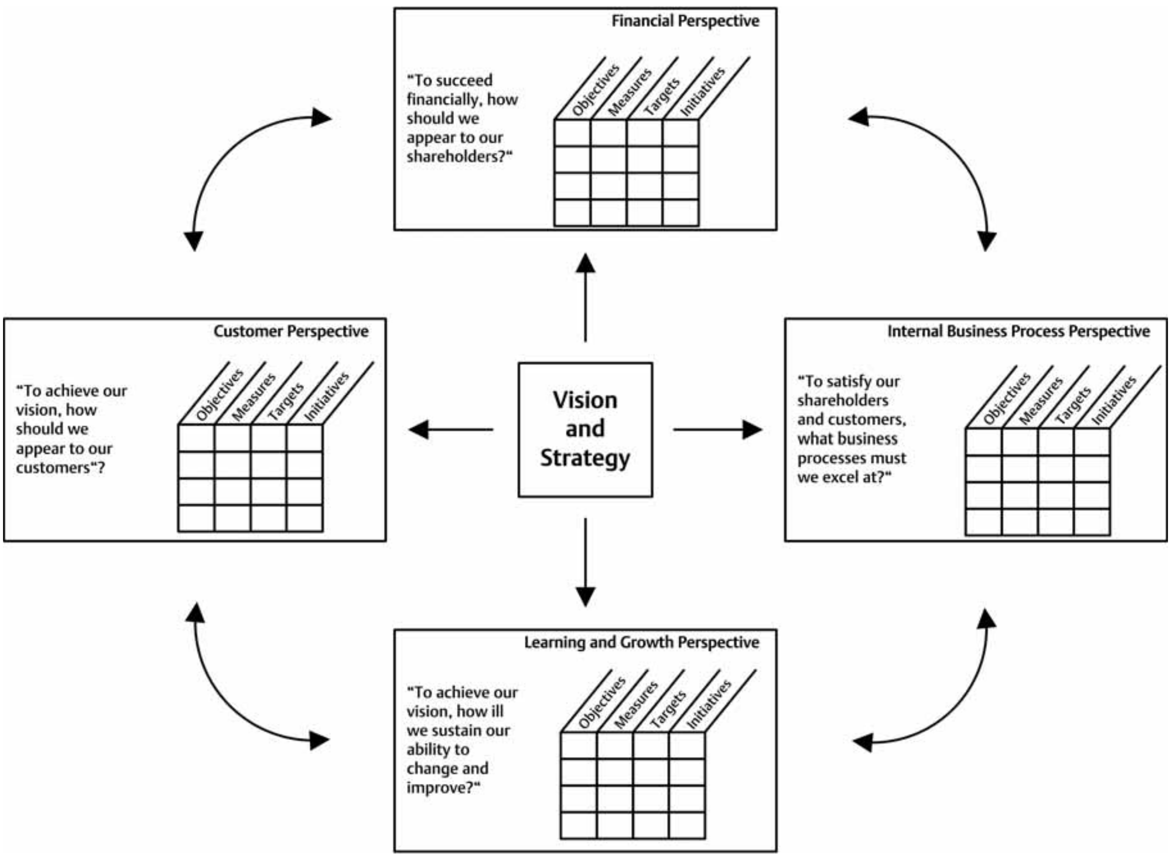
Figure 4-19: Integration of Workflow Audit Trail Data

operative management and control system through guidelines, specific targets, budgets, and other constraints and directives. In order to perform strategic management and control effectively, information about the actual performance of the organization in light of the strategic goals is necessary. This information can be gathered using performance measurement systems that include both internal and external information. The subject of performance measurement is the implementation and validation of the competitive strategy selected by an enterprise.[620]

[620] Compare Eccles (1991).

Example: Workflow-driven Balanced Scorecard

A popular performance measurement framework is the Balanced Scorecard by KAPLAN and NORTON, which is shown in figure 4-20.[621] The Balanced Scorecard provides four different perspectives, which contain objectives, measures, targets, and initiatives. The perspectives group these elements with focus on the financial performance, internal business processes, customer perception, and internal learning and growth. Each perspective should contain a balanced selection of leading and lagging indicators that are related to the measures defined in the individual perspective. Lagging indicators reflect the operative behavior of the company from an ex-post perspective. A typical example of this are financial ratios that reflect the performance of a business unit over a previous time period. Leading indicators provide information about the current behavior of the organization and are used to determine, whether the company works in compliance with the strategy goals or against these goals.



Source: Kaplan, Norton (BSc) (1996), p. 9.; Kaplan, Norton (Use) (1996), p. 76.

Figure 4-20: Balanced Scorecard Framework

621. Compare Kaplan, Norton (BSc) (1996); Kaplan, Norton (2001).

On the implementation side, the Balanced Scorecard is not restricted to the strategic management level. It can be decomposed hierarchically in order to communicate the business strategy from the strategic to the operative system of the enterprise.[622] On the basis of strategic targets, objectives, and initiatives, operative strategies have to be developed by the operative management and control unit to satisfy these targets.

A workflow-based controlling system can provide source information for the computation of ratios within the strategic Balanced Scorecard. Through the timely provision of process and activity frequencies, process indicators within the internal business process perspective can be determined with ease. Also, certain aspects of the customer perspective, such as faithfulness to negotiated deadlines, and the adherence to process design principles such as "one face to the customer" can be evaluated using workflow audit trail data. If customer-facing activities can be identified at the model level, a comparison of process participants in relation to different customer IDs or customer types provides information on the number of different contact persons a customer has to deal with across a process, or the profile of all customers that a particular member of the organization is responsible for.

4.5 Summary

In this chapter, we have illustrated the design requirements of a workflow-driven process controlling system. Starting with a review of related work, we have analyzed three commercial workflow management systems and compared the content of their audit trails to a reference model provided by the Workflow Management Coalition. Based on the findings of this analysis we have developed both a reference model for workflow application concepts, and a reference model for workflow audit trail data. We have shown, how this data can be integrated into data warehouse infrastructures, and have illustrated the usefulness of workflow audit trail information using a cybernetic feedback model that differentiates between automated feedback, operative management and control, and strategic management and control. In the next chapter we discuss the application of these concepts in an industry case, and show the implementation of these concepts in a research prototype.

622. Compare Wiese (2000).

5 Process Controlling: A Case Study and A Prototype

The first four chapters of this book looked at process controlling from a conceptual perspective. We first established the role of process controlling in contemporary organizations. We then looked at technological developments in the area of process management and workflow automation that lay the groundwork for the creation of process controlling systems by providing detailed audit trail data. Based on our findings, we outlined the requirements for the design and application of workflow-driven process controlling systems. In this chapter we take a look at process controlling in corporate practice. We describe the case of an insurance company that realized deficiencies in its existing management information infrastructure, and illustrate the expected benefits this company hopes to derive from a process controlling solution. Furthermore, we describe the design and features of the process controlling prototype *Cassandra*, a system that implements some of the concepts outlined earlier in this book.

5.1 Process Controlling in an Insurance Company

5.1.1 Case Outline

In the following section we outline the practical relevance of our framework by means a case study. The case study was conducted at a medium-sized German insurance company with 1,200 employees between the years 2000 and 2002. The company had conducted an enterprise-wide business process re-engineering project two years before the case study started. Over the course of this project, the major business processes in the insurance-specific departments of the company had been documented and grouped into process clusters. These clusters were compared with application functionality provided by the company's mainframe computer system. Processes were split along the different application transactions that were part of the insurance applications. Based on self-statements by employees, average processing times for activities were documented using a basic resolution of minutes. Based on the identified activity structure and the estimated resource utilization in these activities, an activity-based costing system (ABC) had been implemented, which was used for enterprise controlling purposes.

After the new system had been in use for two years, it was apparent that the underlying business processes had evolved. In addition, information that was required for managerial purposes, such as capacity planning during seasonal peaks in workload, could not be obtained from the existing system. A project was set up to investigate the potential benefits of a workflow-driven process information system for the company.

5.1.2 A First Assessment

In a first step, existing metrics and measurement points were analyzed in interviews with corporate management, enterprise controllers, and division heads. It became apparent that quantifying the actual workload in the organization was very difficult, since traces of work only existed if transactions in the mainframe system were executed. Work that did not result in these electronic transactions did not show up in the controlling applications. Customer inquiries by phone and mail - which were very frequent - typically triggered some follow-up activity, but rarely resulted in a traceable transaction in the mainframe system. Thus, the actual frequency and distribution of process instances was known only to department heads from their personal experience. Log files from the transaction processing system reported the frequency of individual transactions over a period of time (e. g., how often transaction "issue homeowner's policy" was executed in March 2004). They were thus decoupled from the actual content of transactions, and did not allow the drill down into individual cases, or the identification of customer properties that might affect processing times.

The current workload of staff members could not be determined automatically. On a regular basis, department heads would conduct a walk-through and ask their staff members to count open cases on their desks, but this information was not easily available for overall scheduling purposes. Work would be dispatched based on the personal assessment of the department heads with some formal rules in place, such as case allocation based on the first letter of the customer's surname. Proxy relationships were formalized, but the documentation of an open case was not easily accessible, as paper files had to be physically transferred between desks, and supporting documents had to be requested from a document archive, with a turnaround time of one day. Staff scheduling was rather conducted based on experience from prior seasons, but not guided by accurate metrics.

Another shortcoming was the lack of information about processing times and process instance states. Incoming mail was date-stamped, and this date could be entered during further mainframe processing, but this information was optional and frequently not maintained by the employees. It was therefore unclear, how much time elapsed on average between the receipt of a piece of mail and subsequent processing in the receiving department. Lost or misplaced cases and documents were not unusual, and typically these cases were brought to the attention of managers by customers, who inquired about the status of their requests.

Based on this assessment, the benefits of using process audit trails for monitoring and controlling purposes were evaluated. Table 5-1 shows the difference in auditing accuracy without and with audit trail information.

Without Audit Trail Data	With Audit Trail Data
Recording of mail receipt date through manual input (optional)	Recording of detailed process and activity turnaround times, independent of user interaction
Recording of transactions within mainframe applications (processes without transaction processing content are not recorded)	Recording of all process instances
Computations based on average values (e. g., average duration of all car accident claims in one year)	Computations based on detailed analysis of time and volume
No drill-down possibilities to the level of individual business cases	Drill-down possible

Table 5-1: Audit Trail-based Information Availability

5.1.3 Information Availability

The existing activity-based costing system (ABC) was analyzed in the next stage of the project. The goal of this phase was to identify the suppliers of raw data for further analysis, the transformation operations performed on this data, and the results that were delivered by the ABC application. The results of this analysis are summarized in figure 5-1. The system was characterized by a variety of data feeds, most of which were transferred and converted in a manual, laborious process. The activity structure of the existing business processes was transferred manually from Excel sheets into the proprietary ABC-system.[623] These activities were derived from the results of the re-engineering project mentioned above, and it was clear to the parties involved that the activity structure might no longer represent the current state of the enterprise processes - but since no alternative information was available, the existing activity breakdown was utilized. Transactions from the operational insurance application systems were assigned to activities according to a transformation schema developed during the re-engineering project. Since the number of transactions were recorded in the legacy system, the log files were used to compute the actual number of activities performed over a given period of time. These frequencies were then mapped to the activity structure, which was not a 1:1 representation of the application transactions, since some transactions mapped to multiple activities. In these cases, a pro-

623. The enterprise controlling department relied on BOC Adonis for some activity-based costing evaluations, and SAS as a platform for a data warehouse application, which was being deployed as the project went underway. Remarkably, the responsibility for the data warehouse application lay within the hands of a single programmer/analyst - for a company with 3,000 employees.

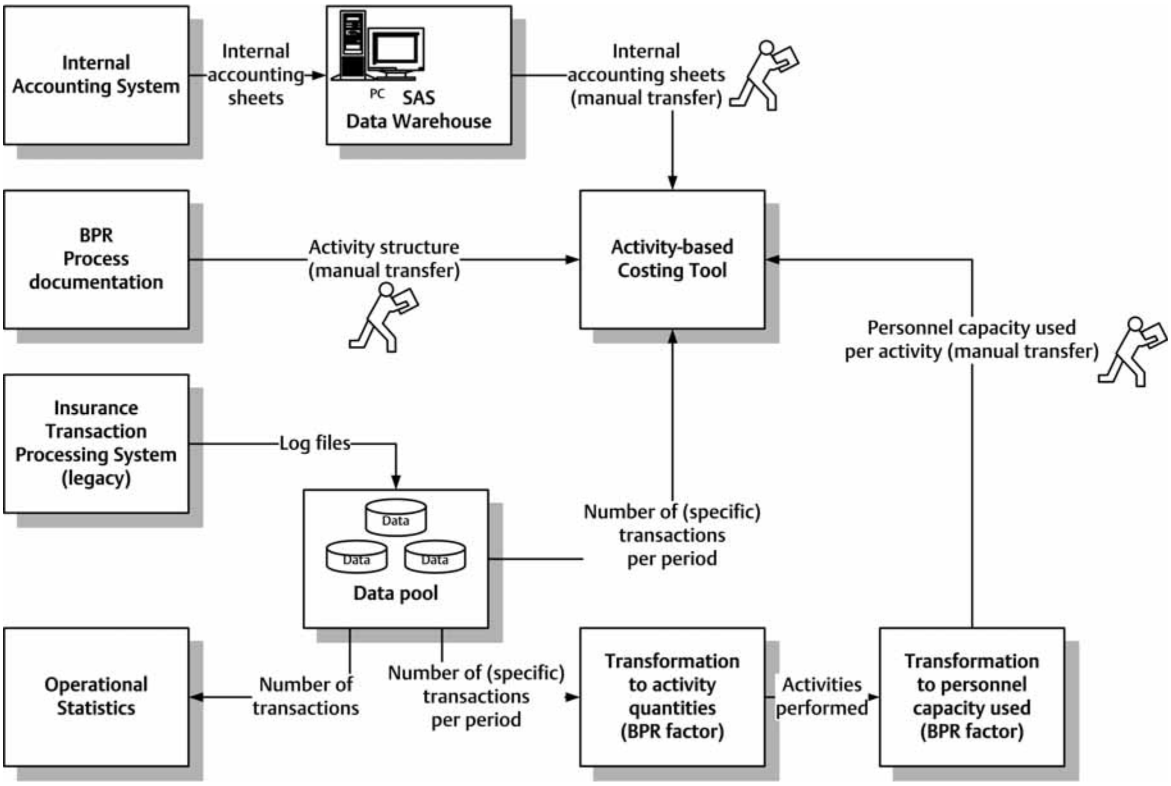


Figure 5-1: Controlling Data Flow (As-Is)

prietary *BPR factor* was used (also known as "magic number"). Using estimated processing times per activity, the required personnel capacity for each activity per period was computed using a custom Excel application. In essence, the frequencies from the transaction logs were multiplied with the self-assessed processing times, and adjusted using another BPR factor. The result of this transformation process was the (more or less realistic) resource capacity used per activity execution, which served as one input factor for the ABC application. This data was combined with the documented activity structure from the re-engineering project. In addition, the activity frequencies recorded in the transaction logs were imported into the ABC application (thus being reused for a different purpose than determining personnel capacities). Financial information about resource valuation was derived from the internal accounting information system. This information was collected in a data warehouse application and manually transferred into the ABC-system. Based on these input factors, the enterprise controller would then calculate process and activity costs, such as the average cost for maintaining a renter's insurance per year.

The entire data transfer and evaluation process was time-consuming and error-prone, due to many media-breaks and manual transfers. In addition the results of the ABC-system did not reflect the actual operations at the insurance company. For example, only those processes appeared in the ABC-system that resulted in the execution of a traceable transaction in the transaction processing system. Using this information, the ABC system documented 20,000 cases of customers cancelling their car insurance policies annually. However, the actual number of cancellations was much higher, since many customers could be convinced to revoke their cancellation request before it was put into effect using the transaction processing system. These cases did not appear in the ABC-system, even though their processing took time and consumed resources. Furthermore, changes to the transaction processing system jeopardized the link between the BPR activity structure and the transactions recorded in the application log files, since the measured amount of time necessary to perform a certain activity was tied to the transaction used within the activity. When a transaction was changed, the processing time for the associated activity was affected, but this change was not documented anywhere. However, one crucial assumption stuck out that questioned the validity of the entire ABC evaluation: Full resource utilization. The calculation of resources necessary to perform an activity was based on the assumption that all employees of the company worked productively during the time they were being paid for. There were attempts to soften this assumptions through the use of the BPR factors mentioned above, but slack time or idle times were not taken account in the ABC calculations. Instead, available resource capacity was determined by multiplying the number of employees in a department with their work time. This number was then divided by the number of recorded activity instances in this department, and the result was regarded as the actual amount of resources utilized per activity execution.

5.1.4 Improvement through Workflow Data Integration

Based on the findings of the ABC system analysis, the project team designed the concept for a workflow-driven process warehouse. This data warehouse was designed to be used as a data feed for the existing ABC application. The resulting scenario is illustrated in figure 5-2. The central component of the workflow-based controlling infrastructure is a process warehouse that serves as the central repository for all operational data that needs to be evaluated. The workflow audit trail is transferred into the data warehouse using two separate import filters. On the one hand, process and activity information is extracted for process perspective evaluations. On the other hand, resource information, i. e., which resource performed which activity, is extracted for resource perspective evaluations. In order to provide semantic information about the overall process composition, process and activity structure information is transferred into the data warehouse at build

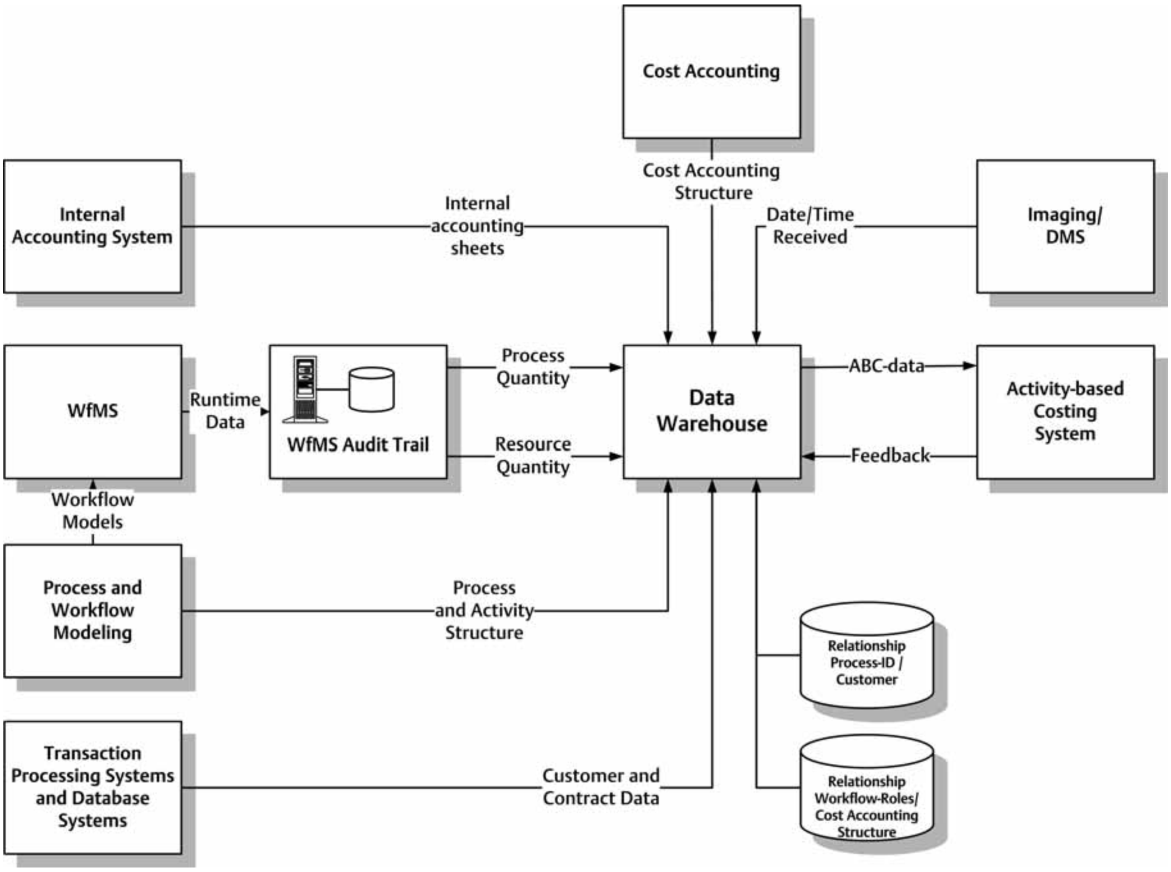


Figure 5-2: Controlling Data Flow (Target)

time. It should be noted that manual activities (e. g., phone calls) will still not be recorded by the new system.

In order to link audit trail information to operational business data, two tables need to be maintained separately. One table contains the relationship between individual process instances and the insurance policies or customer records involved in these process instances. Using this table as a bridge, a drill-down operation from a single process to the customer who triggered the process is possible. The other custom table contains the relationship between workflow participants and the internal cost accounting structure of the enterprise. Since workflow management systems in most cases record a technical ID of the performer who executed an activity, this table is necessary to valuate the resources used in a process with the relevant cost factors.

5.1.5 Preconditions for Implementation

The realization of the process warehouse will enable the insurance company to evaluate its operational business processes in a timely fashion and with a much higher level of accuracy than it is currently possible. However, a process warehouse depends on the existing of supporting infrastructure, in particular a workflow application that provides source information.

In the case at hand, no workflow management system was in place that could supply this information. Furthermore, most documents that entered the organization were moved between workstations in paper form, since no document management infrastructure existed. Archival of documents was performed on microfilm, and the only electronic documents in existence were incoming e-mails and faxes, which were handled through a Lotus Notes application. This led to two alternative implementation strategies:

- The process controlling system could be deployed as an add-on to the existing mainframe applications. However, since documents would still be routed in their paper form, employees would be required to enter additional information manually, in order to capture process and activity start and end time, and to maintain a link between process instances and the physical documents. Clearly, this solution would have increased the workload of individual employees and was therefore undesirable.
- A new document management and workflow infrastructure would need to be deployed prior to the establishment of a process controlling system. This would require a change in existing, paper-based work practices, and require a substantial infrastructure investment, since this infrastructure would have to be deployed enterprise-wide. In light of some rogue document handling projects that had already sprung up within the company, the CIO decided that this was the desirable alternative, and chartered the project team with the mission, to evaluate, select, and deploy a document management and workflow infrastructure.

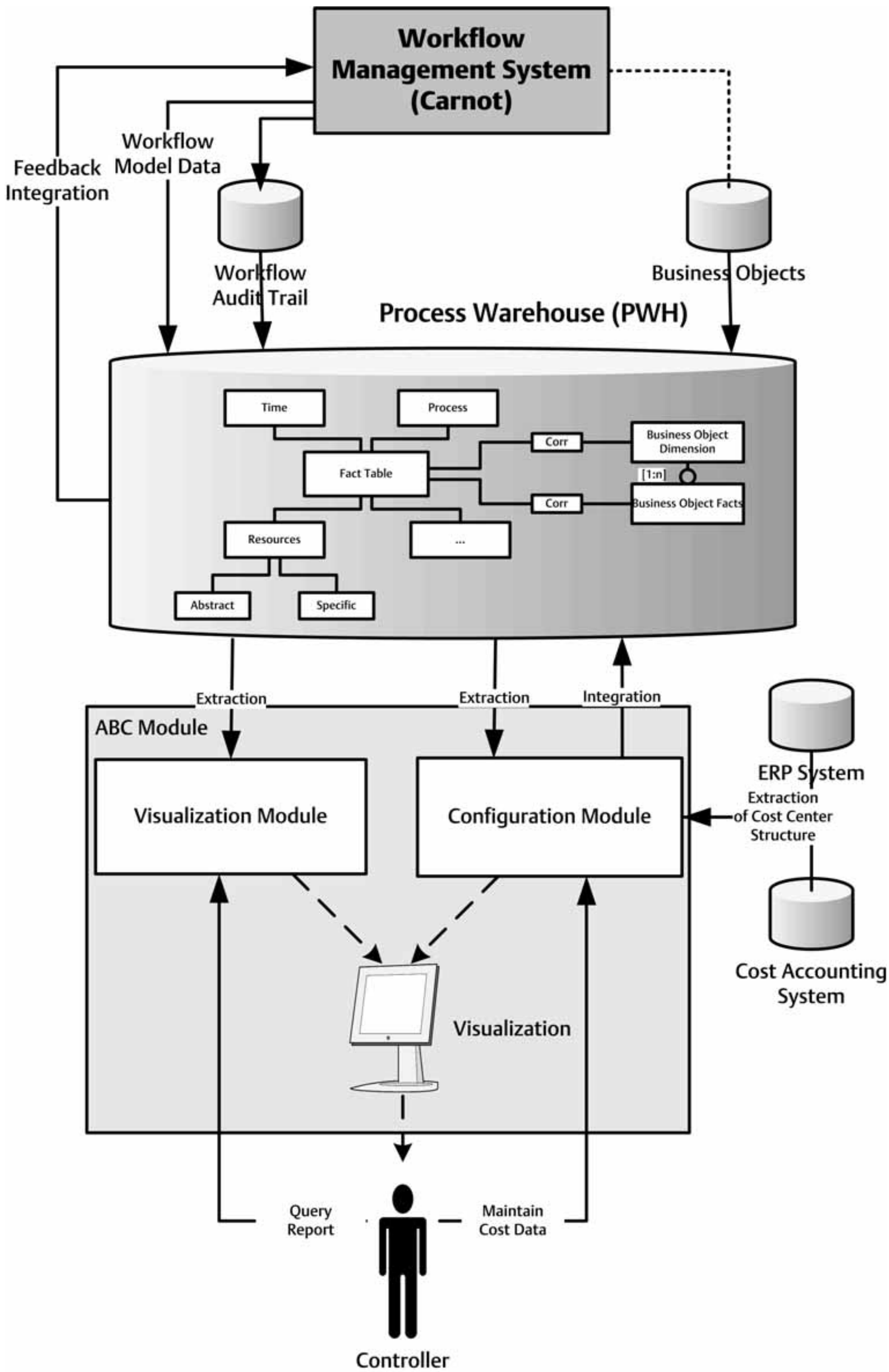
Even though the financial benefits that can be derived from an improved process controlling infrastructure were difficult to determine, the projected financial savings from the introduction of a document management and workflow infrastructure were sufficient to provide a return on investment just three years after the deployment of the new system. The ability to perform detailed process analyses was perceived as an added benefit of the new infrastructure and work packages for the realization of the process controlling infrastructure were added to the project plan.

5.2 Cassandra - A Process Controlling Prototype

In order to validate the concepts presented in this book, we have implemented a process controlling system prototype named *Cassandra*, which offers temporal and frequency-based analyses of audit trail data, support for an activity-based costing module, and a Balanced Scorecard module. The system was implemented in JAVA using Enterprise Java Beans technology. The evaluation components can be deployed in an application server that supports the JAVA 2 Enterprise Edition (J2EE) standard. While the process warehouse and the evaluation components were built from scratch, audit trail information for the *Cassandra* prototype was derived from the commercial workflow management system Carnot Process Engine. Results from the design of the prototype were evaluated by the workflow vendor and an extended and revised version of the prototype is being offered as an additional component by Carnot.

5.2.1 Overall System Architecture

The data model of the *Cassandra* system is implemented in a relational database (Oracle), which is accessed via JDBC. This database hosts the audit trail of the Carnot Process Engine, as well as a variety of data marts for evaluation purposes. Each evaluation method is realized as an individual EJB component, and consists of a visualization component and a configuration component. For instance, the architecture of the *Cassandra* activity-based costing module is illustrated in figure 5-3. The Carnot Process Engine provides process model information and audit trail data for the process warehouse. The existing enterprise cost center structure is manually extracted from a data source, such as an ERP system or a cost accounting system. This information is maintained in the process warehouse through the ABC configuration component. In a fully integrated system architecture, this information would be integrated into the process warehouse through ETL adapters that access the relevant source systems. To keep the prototype simple, the manual integration of cost center data was chosen for the *Cassandra* prototype.

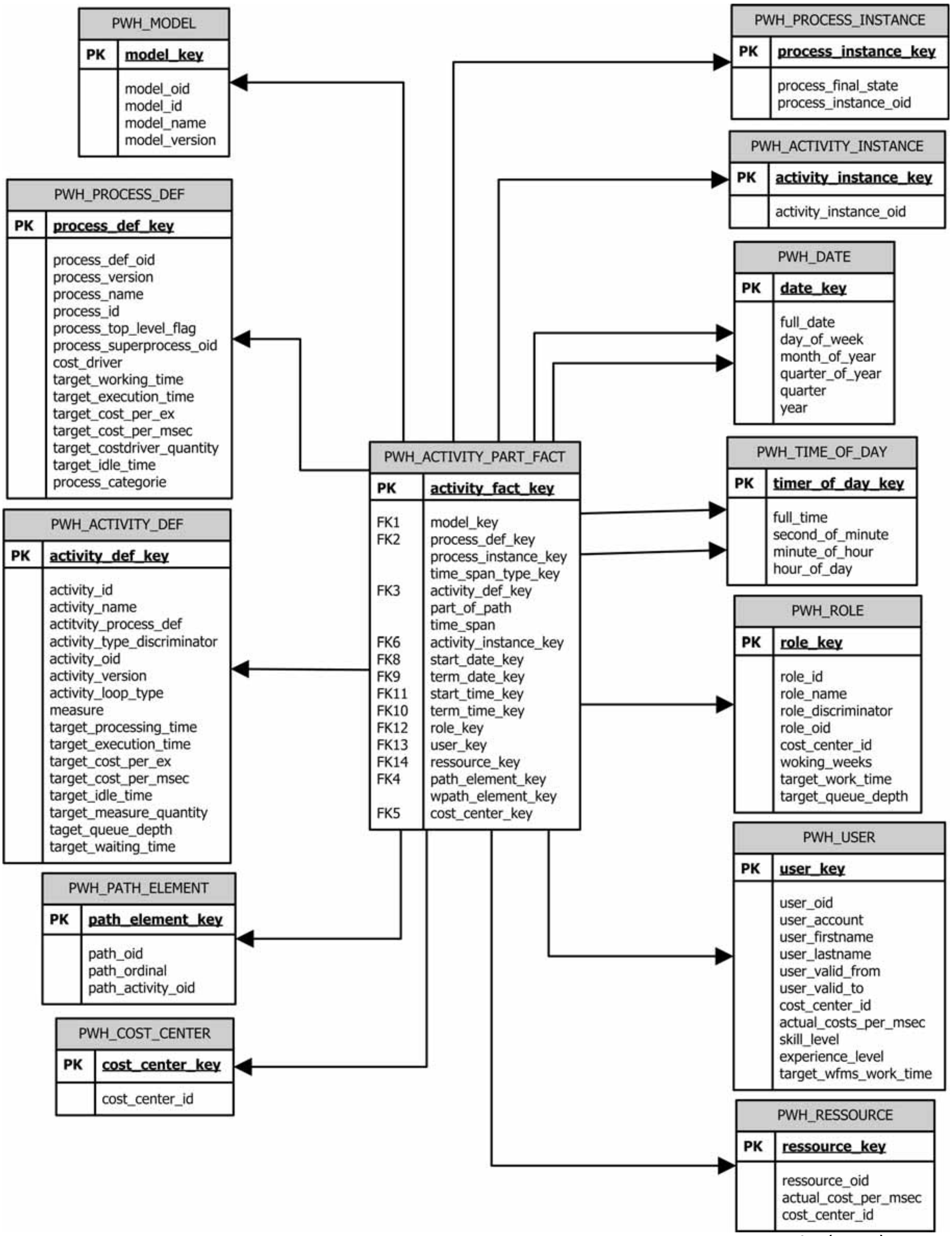


Source: Compare Blum (2002), p. 74.

Figure 5-3: Architecture of the Cassandra ABC Module

5.2.2 Data Structure

The evaluation database consists of the raw audit trail data provided by the Carnot Process Engine, and two data marts for the activity-based costing component, and the Balanced Scorecard evaluations, respectively.



Source: Compare Rieke (2002), p. 120.

Figure 5-4: Cassandra Activity Instance Partial Fact Table

Figure 5-4 shows one of the fact tables of the underlying data warehouse. To simplify the design of different data marts, a number of fact tables that exist at the data warehouse level were replicated and modified at the data mart level. In addition, model attributes of the Carnot Process Engine were modified in order to accommodate necessary attributes for the computation of activity-based costing results. These attributes include information such as the average cost of resource utilization or the relationship between workflow participants and the cost center structure of the enterprise. In a full implementation, the latter attribute would need to be maintained and synchronized with the cost center structure that is typically maintained in separate financial accounting systems.

5.2.3 Evaluation Methods

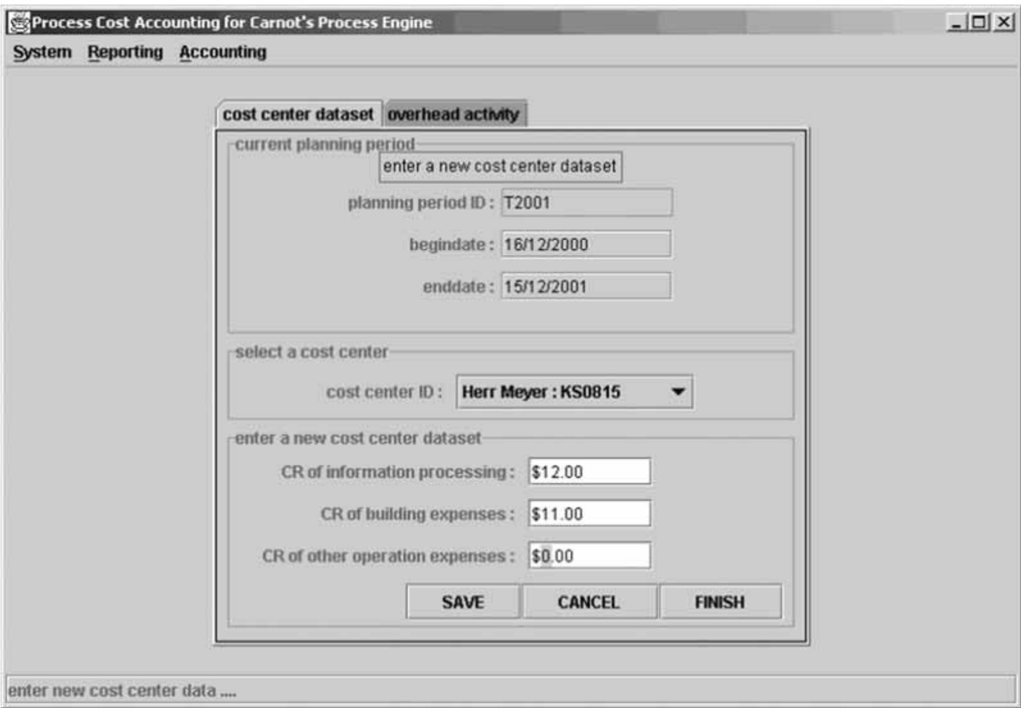
The *Cassandra* prototype contains two evaluation modules: An activity-based costing module, and a balanced scorecard component.

Activity-based Costing Module

The activity-based costing module provides functionality for a financial valuation of processes and activity. It supports the allocation of administrative overhead and direct labor to cost centers depending on the resources utilized during the performance of activity instances. In order to perform the necessary calculations, the corresponding workflow model needs to be enhanced with some ABC-relevant information. For example, the cost centers of the enterprise that are typically defined in cost accounting applications have to be maintained within the ABC module. Figure 5-5 shows the creation of a new cost center for a particular planning period.

For each cost center, a cost factor for the utilization of corporate IT infrastructure as well as a cost factor for the utilization of office space can be allocated. In addition, other expenses necessary for the operation of the cost center can be allocated as well (e. g., location-specific taxes or fees). The cost centers that were created using this module can then be linked to activities and subsequent analyses can be performed. Figure 5-6 shows a cost center report for the cost center shown in figure 5-5.

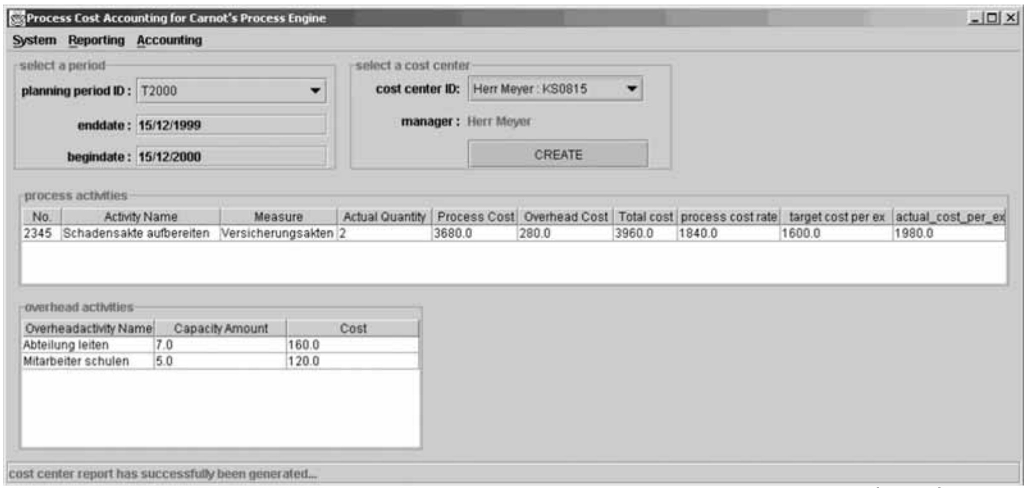
The activity "*Schadensakte aufbereiten*" (maintain customer claim record) was executed twice during the evaluation period and resulted in process cost of 3680 units. During the same period, two overhead activities were performed (*"Abteilung leiten"* = manage department, and *"Mitarbeiter schulen"* = train employees). These activities are computed as a fraction of process activity related work, and cost allocated to these activities are presented in the lower half of the screen.



Source: Blum (2002), p. 112.

Figure 5-5: Definition of a Cost Center

The ABC module allows for the definition of target cost per period and activity execution. In the example, the execution of one instance of activity “Schadensakte aufbereiten” is valued at 1980 units, exceeding the defined target cost of 1600 units.



Source: Blum (2002), p. 114.

Figure 5-6: Cost Center Report

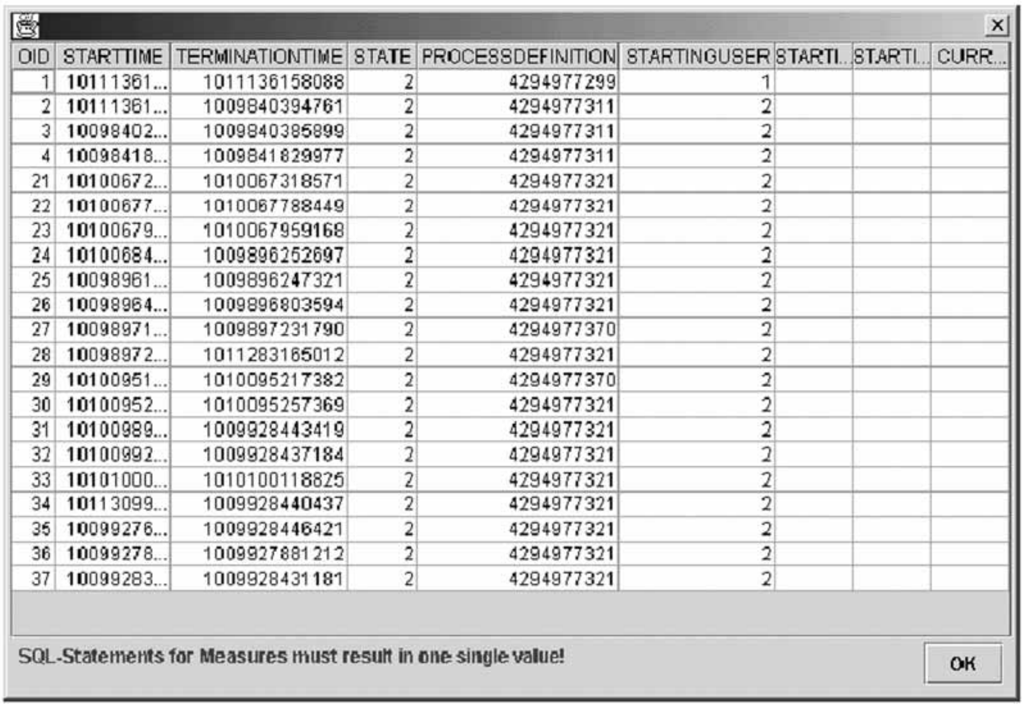
Balanced Scorecard Module

The second evaluation module implemented in the *Cassandra* prototype provides a variety of evaluations for Balanced Scorecard applications. The Balanced Scorecard module uses the process warehouse to provide process-related information within individual perspectives of the Balanced Scorecard. Similar to the ABC component, this module is split into a configuration component and an evaluation component. The configuration component supports the definition of individual Balanced Scorecard perspectives, in order to support domain-specific configurations. For each perspective, different metrics, ratios, and measures can be defined. In order to facilitate the flexible specification of metrics, SQL statements can be used, as shown in figure 5-7.

Source: Compare Rieke (2002), p. 110.

Figure 5-7: Definition of Ratios for Evaluation Perspectives

The screenshot shows a Balanced Scorecard configuration with two metrics defined in the customer perspective: On-time delivery, and customer satisfaction. On-time delivery is defined as the measured deviation from the delivery time that was negotiated with the customer. Using a specific data mart for this purpose, a process analyst can specify this definition using a SQL statement. The validity of this statement can be evaluated using a definition tester function. This is realized through the *check* button in figure 5-7. Upon activation of this button, the configuration module executes the query entered by the used and displays the results in a separate window. An example of this statement evaluation is shown in figure 5-8.

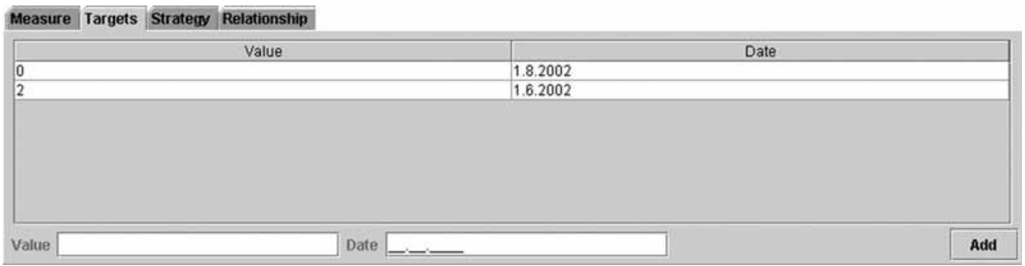


OID	STARTTIME	TERMINATIONTIME	STATE	PROCESSDEFINITION	STARTINGUSER	STARTI...	STARTI...	CURR...
1	10111361...	1011136158088	2	4294977299	1			
2	10111361...	1009840394761	2	4294977311	2			
3	10098402...	1009840385899	2	4294977311	2			
4	10098418...	1009841829977	2	4294977311	2			
21	10100672...	1010067318571	2	4294977321	2			
22	10100677...	1010067788449	2	4294977321	2			
23	10100679...	1010067959168	2	4294977321	2			
24	10100684...	1009896252697	2	4294977321	2			
25	10098961...	1009896247321	2	4294977321	2			
26	10098964...	1009896803594	2	4294977321	2			
27	10098971...	1009897231790	2	4294977370	2			
28	10098972...	1011283165012	2	4294977321	2			
29	10100951...	1010095217382	2	4294977370	2			
30	10100952...	1010095257369	2	4294977321	2			
31	10100989...	1009928443419	2	4294977321	2			
32	10100992...	1009928437184	2	4294977321	2			
33	10101000...	1010100118825	2	4294977321	2			
34	10113099...	1009928440437	2	4294977321	2			
35	10099276...	1009928446421	2	4294977321	2			
36	10099278...	1009927881212	2	4294977321	2			
37	10099283...	1009928431181	2	4294977321	2			

Source: Rieke (2002), p. 108.

Figure 5-8: Measure Definition Tester

For each user-defined measure, specific value targets with a related due date can be specified, as shown in figure 5-9. These targets can be used in the evaluation view to overlay actual measurements with target values, and enable a quick evaluation of performance trends.

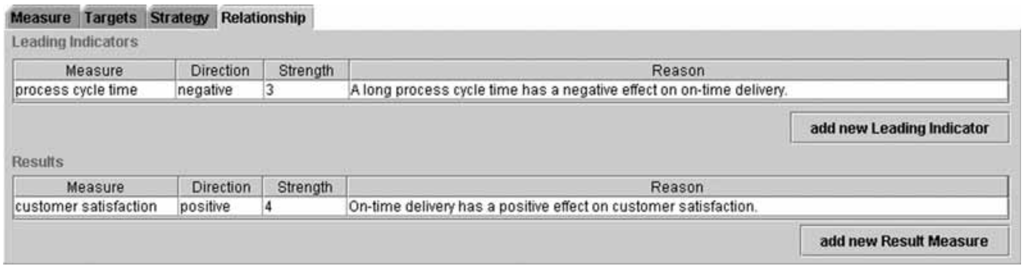


Value	Date
0	1.8.2002
2	1.6.2002

Source: Compare Rieke (2002), p. 110.

Figure 5-9: Target Definition Tab

Another component of the configuration module, the relationship definition tab, enables users to define positive or negative relationships between measures and indicators. Furthermore, the Balanced Scorecard designer can provide an explanation for the chosen relationship, which can later be displayed to the process analyst. The example in figure 5-10 shows relationship between process cycle time, on-time delivery, and customer satisfaction.



Source: Compare Rieke (2002), p. 113.

Figure 5-10: Relationship Definition Tab

In the evaluation view, the process analyst can choose to view the individual ratios in a separate window. For instance, figure 5-11 shows the development of the cycle time for a loan process over time. The horizontal line at the bottom of the window indicates the target processing time, the two curves represent the actual processing time and a weighted mean value for the process cycle time computed over the past 30 days. A mouse pop-up provides users with detailed information about the process duration on a specific day, if the user "hovers" over a particular point of the diagram.

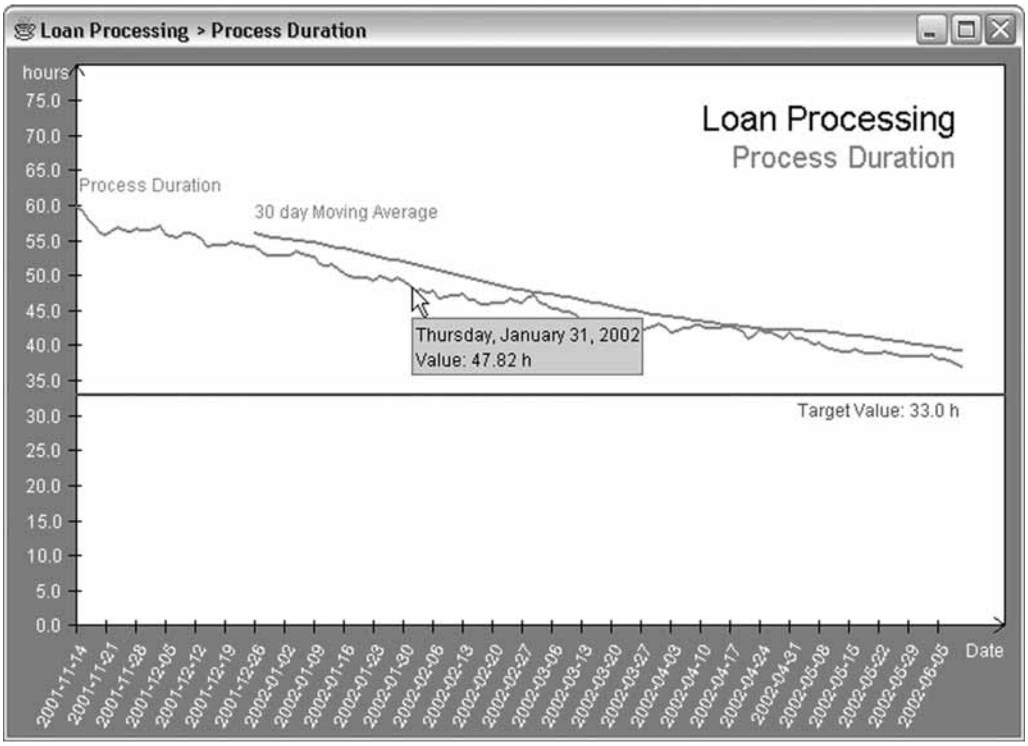


Figure 5-11: Measurement Viewer

5.3 Summary

In this chapter, we have illustrated the commercial interest in workflow-based process controlling approaches by means of a case study. We were able to clearly identify the business value of workflow-based process controlling information by comparing the information derived from such an infrastructure with an existing ABC application. However, we have also shown that in many cases infrastructure investments may be necessary, before the benefits of a process controlling infrastructure can be realized. In order to demonstrate the validity our approaches, we have implemented a research prototype. It should be noted that the prototype was intended as a *proof of concept*, and has not been deployed in a commercial environment. It has, however, influenced the implementation of a similar component by a workflow vendor.

6 Summary, Reflection, and Outlook

The goal of this book was the design and validation of a process controlling framework based on workflow audit trail information. Process-orientation has been discussed in the organizational literature for more than 70 years, however, the implementation of process-oriented organization structures has found widespread acceptance only within the last 15 years. While the structuring of organizations along their processes has been extensively discussed in scientific and popular publications, the operational realization of process management and controlling, and the design of suitable management information system support have received considerably less attention. In order to bridge this gap, we have developed a methodical approach for process-oriented controlling based on workflow audit trail data.

Based on a system theoretic view of organizations, we have identified different roles of management and controlling at the strategic and operative level of organizations. We defined the goals and functions of process management and controlling and combined them with properties of process-oriented organizations. Our findings led to the development of a comprehensive process life-cycle.

Process management and controlling ensure the efficiency of operative enterprise processes. At the strategic level, process controlling ensures that all organizational processes cooperatively support the organization's goals. This purpose requires a unified process measurement framework. At the operative level, process controlling ensures the efficiency and effectiveness of individual process enactment. This task requires timely and precise information about the operative behavior of business processes.

Workflow management systems support process-oriented organizations through the automated coordination of activities, resources, application systems, and data along a formal workflow model. During the enactment of workflow instances, audit trail data is produced. Audit trails precisely record the execution of process and activity instances through the recording of events. Even though an official standard for audit trail data exists, this standard has not been implemented by most workflow vendors. Furthermore, the format of the current standard does not satisfy all requirements of a process controlling system.

In order to overcome this dilemma, a reference meta model for workflow audit trail data was constructed in an inductive fashion. We gathered data through the study of commercial workflow systems and available standards, and used the results of this analysis in the design of the reference meta model. We were able to demonstrate the integration of audit trail information based on this meta model into a generic process controlling infrastructure at the level of data integration. We discussed evaluation perspectives for workflow-based controlling information, and created a cybernetic feedback model for multi-level process management.

Through an exploratory case study of an insurance company we illustrated the relevance of the topic. Based on a detailed analysis of the existing controlling infrastructure we were able to document the potential benefits of a workflow-based process controlling infrastructure.

The feasibility of the proposed approach was demonstrated through the implementation of a process controlling prototype, based on a process warehouse. We documented the details of an activity-based costing module and a Balanced Scorecard module, and thus illustrated the application of well known controlling instruments to workflow audit trail information.

Evaluation

The contribution of the process controlling approach developed within this book can be evaluated against empirically validated quality requirements for controlling applications:[624]

- *Controlling has to start at the customer.* The integration of information from market partners into the process controlling infrastructure is an important feature to enable early warning indicators (e. g., to forecast and remedy delayed deliveries). The increasing use of workflow-based web services allows companies to integrate audit trail information from business-to-business processes with internal workflow audit trails. In order to enable controlling across concatenated process chains, global process models and matching correlation keys need to be introduced, and an integration of different audit trail formats into a unified schema is required. The audit data reference meta model developed within this book provides a unified model of audit trail information, regardless of the underlying workflow implementation.
- *Controlling has to take place in the heads of the employees.* In order to raise the awareness of process orientation among employees, monitoring and controlling mechanisms should be accessible from the workplace of every process participant. The communication of target values and the continuous monitoring of process metrics enables process participants to evaluate the status of process and activity instances. They can

624. Refer to Horváth, Seidenschwarz, Sommerfeldt (1993), p. 81.

use performance indicators such as predicted completion time or on-time performance. The process controlling framework presented in this book reflects this through the active notification of workflow participants in the case of target deviations as well as the presentation of workflow information at the operative and strategic level.

- *Start immediately and improve continuously - especially processes.* As soon as a workflow-based application system is deployed within an organization, audit trail data is available. Detailed controlling requirements should be observed during the design of workflow models, but they may also be added later on. Even simple time- and frequency-oriented analyses on the basis of raw audit trail data provide valuable information about the process performance of an organization. In chapter 4 we have presented a reference data model for a process warehouse. This reference data model enables companies to integrate workflow audit trail information into a corporate data warehouse, and subsequently create subject-oriented data marts.

- *Everybody needs to understand the control measures.* Workflow management systems coordinate operative activities. The metrics derived from audit trail data relate to these activities, creating an immediate link between the actual workplace of the individual employee and the information derived from a process controlling system. The process controlling framework developed in this book addresses different information requirements at different levels of the corporate hierarchy.

- *Controlling needs to overcome departmental boundaries.* A workflow-based process controlling system provides information along the flow of work, across functional boundaries. This way, it contributes to the creation of a holistic controlling infrastructure. Through the implementation of the *Cassandra* prototype and the integrated activity-based costing module, we have demonstrated that workflow-based process controlling not only supports the logical process structure of the enterprise, but that it can also be used to document product- or customer-related activity clusters.

- *Controlling must not end at the company gates.* The analysis of internal business processes is a first step toward a workflow-based supply chain controlling that integrates information from trading partners into a consistent process database.[625] In order to achieve the cross-enter-

[625]. Compare Holten et al. (2002).

prise integration of process controlling data, a unified data format for audit trail information is necessary, as well as a methodical framework, how this information can be evaluated. The reference meta models provided within this book contribute to this goal.

Outlook

Workflow-based process controlling as a research domain can be approached from a technical, organizational, or methodical perspective.

The development of a purpose-independent audit trail data model is the first step toward a process-oriented data warehouse design. The systematic development of purpose-oriented data marts for process-related analysis methods as well as the analysis of performance issues for process-oriented queries is a research topic closely related to this book. As such, it is beyond the scope of this book.

The application of the hierarchical Balanced Scorecard at a process level enables the communication and translation of strategic plans across different levels of the corporate hierarchy. While the integration of process information into a strategic Balanced Scorecard was outlined in an upstream fashion, the definition of process-oriented initiatives and related measures in a downstream fashion remains subject of future research.

The increasing use of workflow technology as an integration technology for web services creates the opportunity to capture process information across organizational boundaries. The integration of process controlling data along the supply chain, and related questions of privacy, security, data and method integration between business partners, as well as the consolidation of processes views across the supply chain remain some of the most challenging research questions within the area of process controlling.

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Appendix

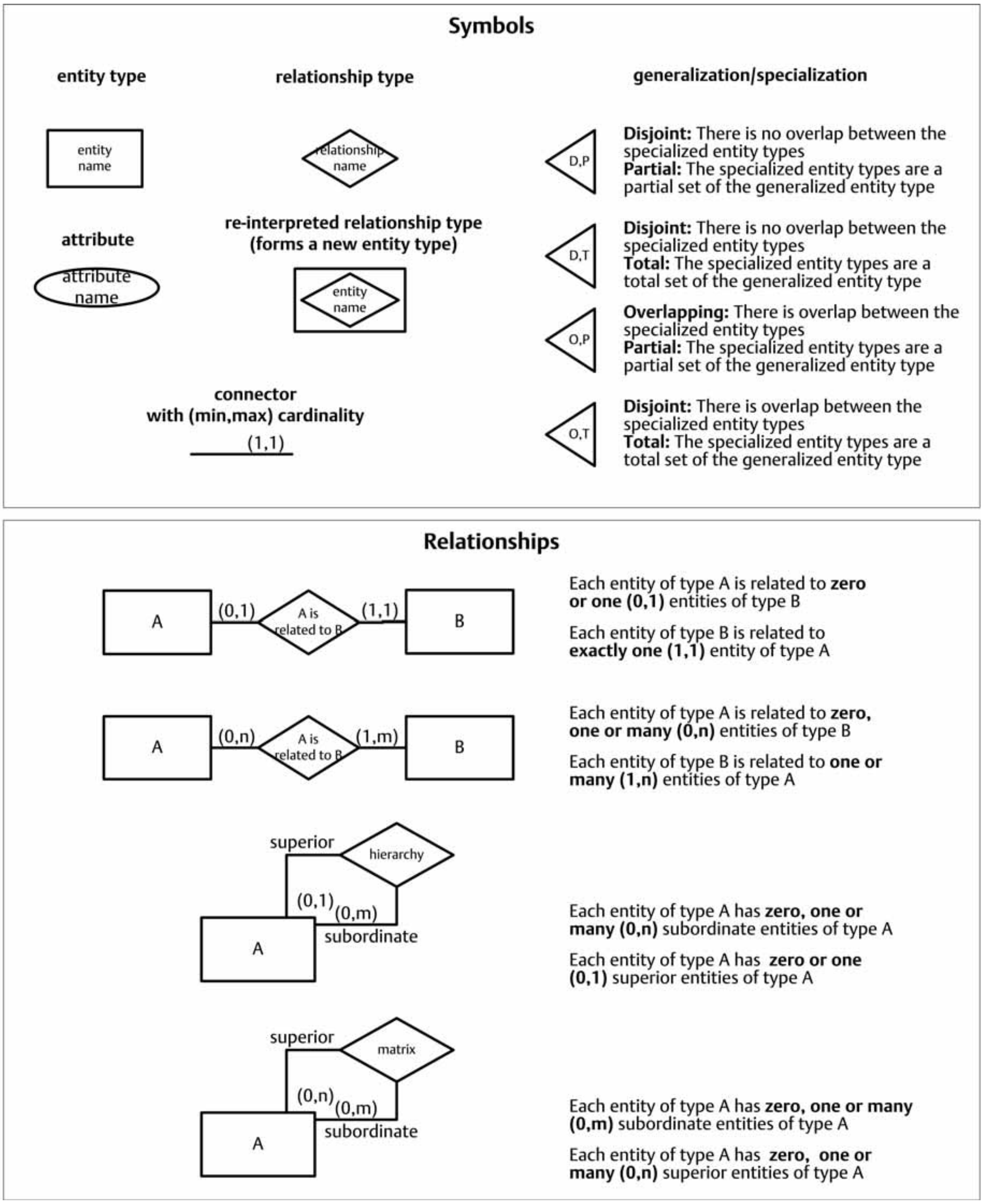

Figure A-1: Entity Relationship Model

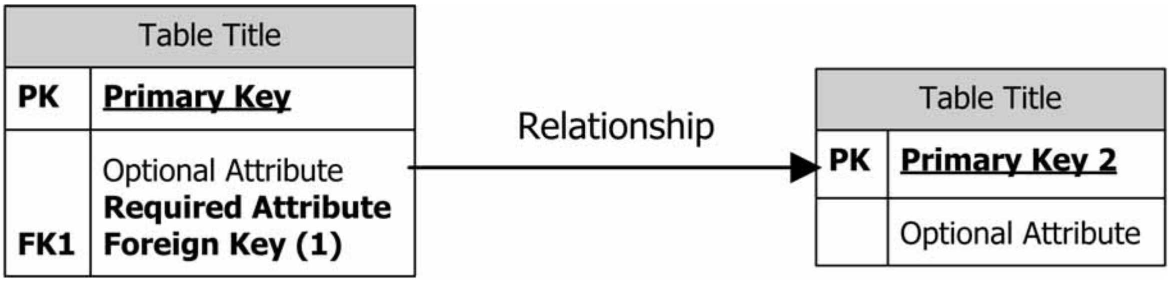

Figure A-2: Relational Model

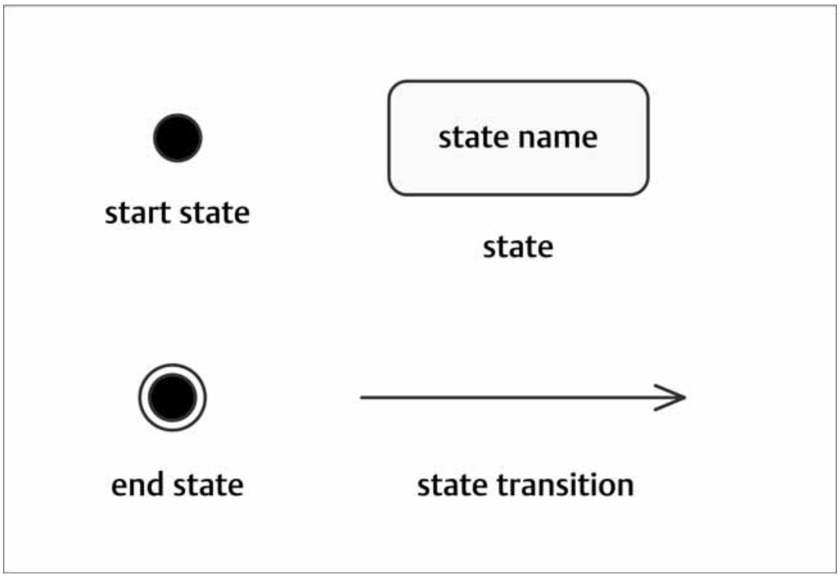

Figure A-3: State Model