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Workflow-based Process Controlling—Or: What You Can Measure You Can Control

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ABSTRACT

The exact and timely analysis of automated business processes through the analysis of protocol data is one factor for the use of workflow management systems in organizations. While in the past the automated routing and distribution of work have been prevailing factors in the marketing of workflow applications, the side-effect of having actual and precise business data for analysis yields many opportunities for controlling and managing business operations that have unfortunately been neglected in the past.

We outline the economic aspects of workflow-based process monitoring and controlling and the current state of the art in monitoring facilities provided by current workflow management systems and existing standards. After a discussion of the three evaluation perspectives, sample evaluation methods for each perspective are discussed. The integration of workflow audit trail data into existing controlling environments and implementation issues are outlined before an outlook on further research is given.

EVOLUTION OF PROCESS INFORMATION SYSTEMS

Workflow-based Monitoring and Controlling

The need to serve customers in global markets and the tendency toward smaller, more flexible, less hierarchical organizations leads to an increasing spatial distribution of companies. This distribution of formerly centralized enterprises on the one side and the (temporary) integration of different companies (virtual enterprises) on the other side lead to the necessity of an organizational and functional connection of the distributed workplaces.

Distributed information systems and Internet-based workflows are the enablers for these kinds of ventures. Recent standards such as Wf-XML [1] foster the use of workflow management systems for these cross-organizational ventures. In combination with concepts such as Customer Relationship Management (CRM), workflow systems enable companies to streamline their processes while maintaining a clear customer focus. The prediction, that in the next few years, companies implementing CRM strategies will have to rely on solutions composed of best-of-breed components (cf. [2]) strengthens the role of workflow management systems as the “glue” in modern business application architectures.

During the enactment of workflow-supported business processes, the automation of coordination increases the efficiency of process execution through the elimination of transport times, the automation of routing decisions and the monitoring of deadlines. However, the actual benefits of workflow management are usually described in vague terms. While the costs for the selection and introduction of the system can be calculated rather precisely, the benefits of workflow automation are more difficult to determine.

Besides quantitative benefits such as decreasing cycle times, reduced personnel cost and (if workflow and document management technologies are combined) document storage space and paper cost, qualitative aspects have to be taken into account as well. These figures include shorter time to market due to process improvement, higher process quality due to decreased error rates and faster response to customer inquiries.

Moreover, while most costs from the introduction of a workflow management system are generated during the system introduction phase, the benefits are generated over a much longer period of time. In order to enable a cost-benefit analysis during the requirements analysis phase of a workflow project, time-adjusted methods of investment analysis are necessary.

The historical data of workflow instance execution provides a valuable source for the analysis of the economic impact of workflow management systems. This historical data can be evaluated either in real-time (monitoring) or during an ex-post analysis (controlling).

Workflow monitoring deals with the analysis of workflow instances at run-time. Active monitoring of the current state of workflow instances can serve numerous purposes, such as the generation of exception reports for overdue work items or early warning reports for potentially overdue work items (Management-by-Exception, cf. e. g. [3]). Passive monitoring upon request can deliver status information about running workflow instances, e. g. for answering a customer inquiry about the status of an order (cf. e. g. [4], [5]). Workflow monitoring can also be divided into technical and organizational monitoring. While technical monitoring is used for performance measurement (e. g. response time, system load etc.), organizational monitoring measures the organizational efficiency (e. g. idle times, workload analysis etc.).

Workflow-based controlling aims at the ex-post analysis of the audit trail data of process enactment (sometimes called strategic process controlling). Here, the single workflow instances are aggregated according to different dimension schemes as described in section 3.

Workflow-based controlling is useful for the detection of long-term developments in workflow enactment and the review of already existing workflow implementations. In order to identify deviations in process execution, the audit trail data is often compared to target data derived from corresponding business process models. The efficient integration of audit trail information within existing repositories such as Data Warehouses is an important factor in the usefulness of the results of workflow-based controlling applications. The positioning of the two phases is shown in figure 1.

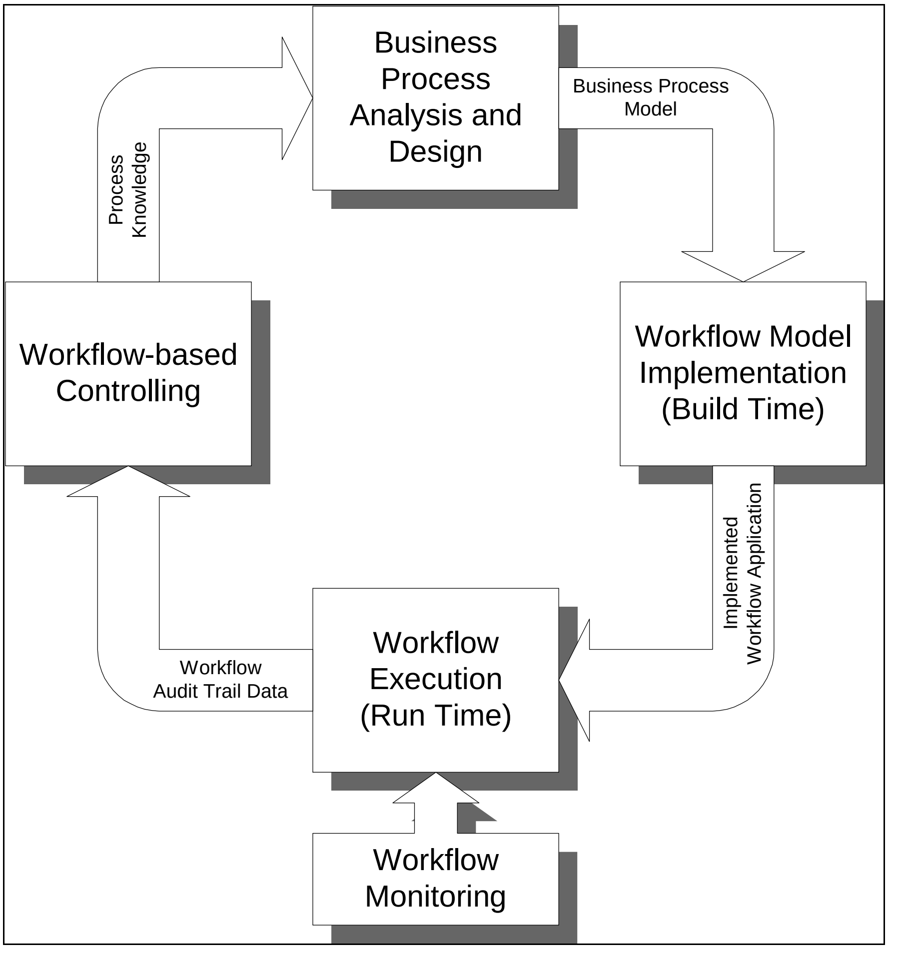


Figure 1: Workflow Life Cycle (adapted from [6]).

With the distribution of information-processing facilities in enterprises as described above, the stakes for management information systems increase, because the executives now have to be provided with relevant information from distributed processing sources, independent of the source or the destination of the information requested.

This development leads to new problems in the design of process information systems. For example, the enactment of a process by parties around the globe may lead to the situation that a performer in Munich executes one activity, while the next activity is executed in New York. If the audit trail data (i. e. the logged history information about the activity enactment) reflects the local time of enactment without specifying the time zone, an analysis of the process might show that the second activity was executed before the first.

Process Controlling in the Workflow Project Plan

Process monitoring and controlling is primarily not a technical issue, but an organizational one and, as such, it is of high importance for all process management initiatives. Besides the obvious technical

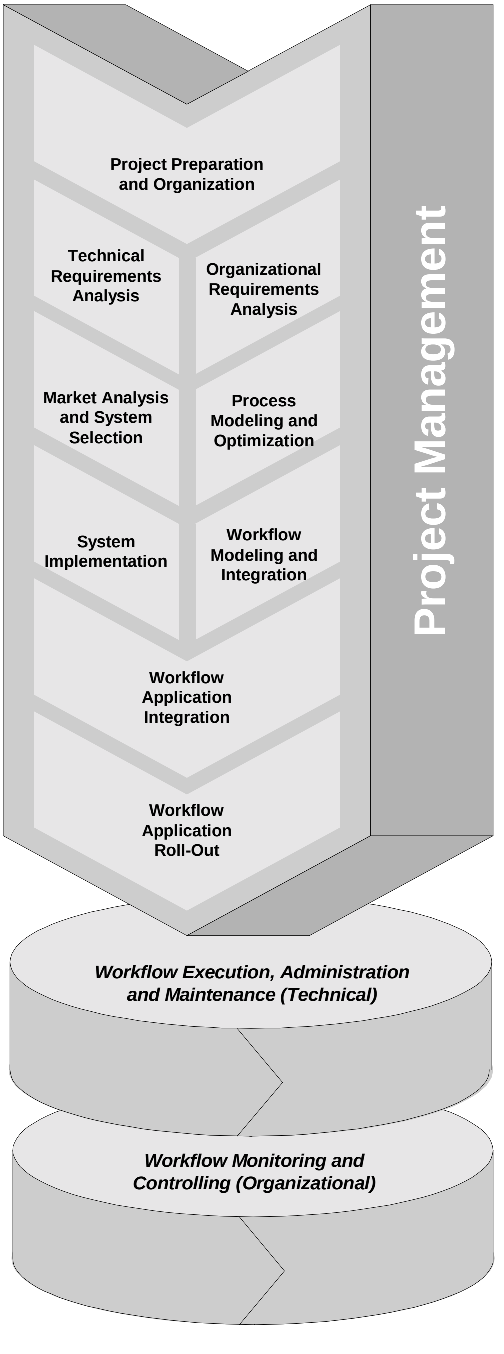


Figure 2: Procedure Model for Workflow Application Development and Deployment

questions of integrating different data sources, converting data formats and relating data from operative information systems to audit trail files, the establishment of an organizational process ownership that uses the newfound knowledge about process execution is one important step during the introduction of a workflow application.

Figure 2 displays a generic procedure model for the development and deployment of workflow applications. During the initial project phases, both organizational and technical requirements of the workflow application have to be defined. The results lead to a technical system evaluation and an organizational selection, modeling and optimization of those business processes that should be automated using the workflow system. These processes must be modeled in order to have a common understanding of the processes. The results of this activity are as-is process models, which are to be discussed by the project team. To-be process models describe the new process design and document the result of all process optimization efforts. The implementation of the new processes requires organizational and technical activities like the configuration of associated ERP modules, the introduction of workflow-based applications or the training of new staff members. These activities are intertwined in various ways (for reasons of simplicity, these mutual influences are not represented in figure 2). The final stage of the project is the rollout of the final workflow application, followed by the continuous administration and maintenance, representing the technical supervision of the system. Process monitoring and controlling can be seen as a parallel continuous activity, which covers the business aspects of the system operation.

The main objective of process monitoring and controlling as an embedded task within such a holistic process management is to provide the necessary data basis for continuous process change management. This extends the reorganization efforts beyond the first initial implementation of new processes.

The data gained through the monitoring and controlling of data can be used for two purposes. On the one hand, the performance of business processes can be evaluated. On the other hand—and in addition to this main objective—process monitoring and controlling is useful to measure the value of the IT investment necessary to improve the processes. The main IT infrastructure of process monitoring and controlling is a workflow management system. The effects related to a workflow management system can be distinguished in monetary and non-monetary effects.

Selected monetary effects of the use of a workflow management system are:

- Reduced processing times (personnel cost)
- Reduced transport times (personnel and resource cost)
- Reduced storage costs (for paper archives)

As a consequence, an IT system for process monitoring and controlling needs interfaces to applications like HR systems, financial accounting, cost and revenue accounting, and asset management.

More often, it will not be possible to measure the economic effects of a workflow application on a monetary level. Examples of these kinds of non-monetary effects are:

- Digitalization of routine work, leaving more time available for valuable work
- Reduction of error frequency and error types
- Higher quality of process documentation and status information
- Qualification-adequate assignment of work-items through staff resolution
- Evenly distribution of work-items through role-based participant definition

Measuring the economic effects of workflow applications depends largely on the availability of information for analysis. This aspect is discussed in detail in the next section.

MEASURING THE IMPACT OF WORKFLOW TECHNOLOGY

Information Availability

The information available for process analysis varies with the workflow management system used. Most workflow management systems record only technical events during the execution of a workflow, such as the instantiation of a workflow instance, the availability, execution and completion of activities (with or without the ID of the participant that executed the activity, depending on the implementation and/or legal restrictions, such as privacy policies). Only few systems record the object processed within an activity in their audit trail file (cf. e. g. [7]). Nevertheless, without an insight into the actual business content of a workflow instance, only process structure related information can be evaluated. The availability of information determines the quality and depth of the analyses possible.

In order to use audit trail data for business purposes, it is necessary to link the technical process identification to the business object that was processed in this specific process instance. In many cases, this can be accomplished simply by implementing a (background) activity that records the identifiers of the process and the process object, e. g. an insurance claim number or a customer case ID.

In order to enable an object-view based analysis of workflow instances during the development of the process information system PISA (which is described in [8]) an activity was inserted into the workflow model. This created a log-entry that contained the relationship between the workflow instance ID and the process object ID, which was not available in the audit trail data of the workflow management system. Using this additional information, a drill-down analysis from the process information to the process object could be implemented.

The majority of workflow management systems record three types of data: State-changes regarding processes and activities, resource information about the generators of the state-changes and timestamps of the state-changes. This information from the workflow audit trail files can be used for a number of analyses in a process information system:

- Time of events: Using the timestamp of the activation, execution and completion or abortion of workflow activities, a process information system can compute process cycle times, lay- and idle-times as well as activity processing times and their deviations. A forecast of potentially overdue activities as well as a preliminary turnover time can be determined.
- Involved resources: The information about the organizational entities and information systems involved in the execution of activities can be used to compute the average and peak workload of resources. The change in processing time of activity instances over time that were executed by the same resource indicates potential learning curve effects. The number of different resources involved in the execution of a

single workflow as well as in a set of workflow instances can provide information about the input-output relationship of a process.

- State-changes: The kind and number of state-changes in a process provides information about the number and type of exceptions that occurred during the execution of the process (for example, if a workflow changes frequently from "running" to "suspended"). The analysis of active workflow activities within single workflow instances can be used to determine the probabilities of execution paths in case the workflow model contains parallel branches. This information can in turn be used for simulation purposes.

Besides those elementary information objects, advanced analyses such as effects of workflow on the time to market, changes in process quality or competitive advantage are useful in order to assess the economic effect of a workflow management system. However, the strategic importance of the information is directly inverse to the measurability of this type of information (cf. figure 3).

While operative, (such as substitutive) effects of workflow technology can be measured rather easily (e. g. the reduction of personnel during process enactment); complementary effects such as job enlargement and enrichment for workflow participants are more difficult to measure. Substitutive effects are also regarded as being calculable, while complementary effects involve some estimation. Strategic effects of workflow technology, such as the ability to deliver new types of products to customers or a shorter time to market can no longer be determined in monetary figures.

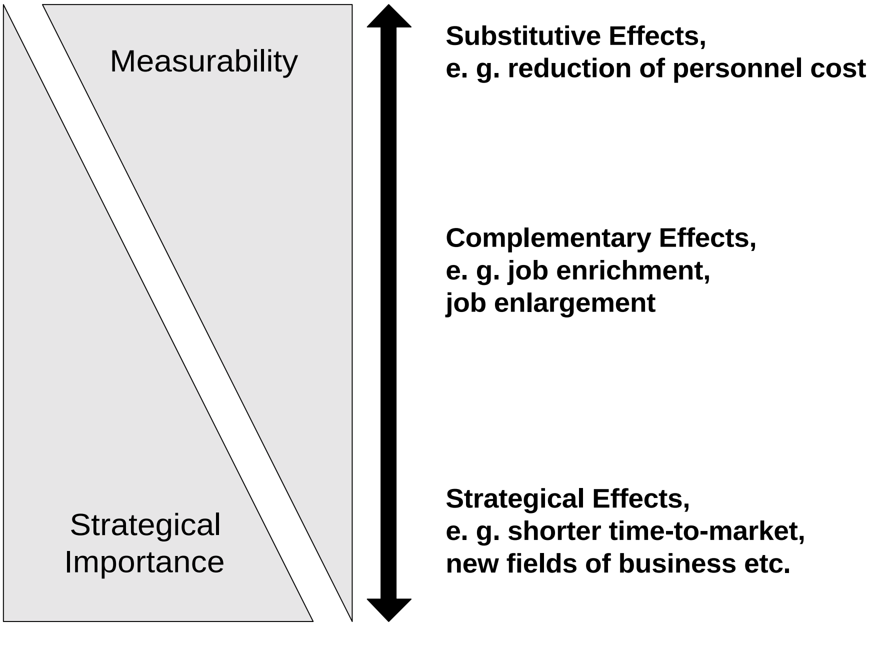


Figure 3. Impact and measurability of economic workflow effects

Activity-Based Costing using Workflow Audit Trail Data—A Real World Example

In the 1980s, many companies moved from Traditional Cost Accounting systems toward activity-based costing as an analysis method, which allows calculating products and processes based on their actual resource utilization as opposed to the capacity-oriented traditional accounting methods [9]. Frequently, activity-based costing is used from an ex-post perspective to assign the (known) overhead cost from the last period to processes and activities.

The use of workflow audit trail data can improve the data quality significantly and enable the enterprise to calculate processes and products more precisely. In the following, a typical example from a German insurance company is given.

For insurance companies, like other types of the service industry, a large percentage of the overhead cost consists of the employee's salaries (in our example, up to 70 percent). In order to enable a calculation of products based on the actual cost of e. g. Processing a car accident claim, the enterprise uses activity-based costing to assign the annual overhead cost to the different processes and activities executed within the enterprise.

Because the existing controlling system did not contain any information about the actual resource utilization in a specific process instance, generalized utilization figures that had been determined during an earlier reengineering project were used for the computation of personnel cost per process. These figures related to an activity structure that had significantly changed over the last couple of years and did no longer fit the current business process structure of the enterprise.

This lead to unsatisfactory results for the management, as for example the execution of the same process type with the same activities for a corporate client takes much longer and creates uses more resources than the same process executed for a private client—nevertheless, the activity-based costing system was unable to differentiate between the two cases.

In addition to the incomplete information available, the existing data processing infrastructure for historic reasons consisted of different applications for different insurance types (car, house, life etc.). These applications provided different data formats and contents for controlling purposes and hinder the analysis of typical customer profiles across different product categories.

One major problem for the controlling department of the enterprise was the fact that only those business processes were recorded, where an actual processing in the existing mainframe system was performed. For example, if a customer requested a different rebate for car insurance and this rebate could not be granted due to an obvious mistake in the customer's application, this process instance was never recorded in the controlling systems of the company.

Also, if a customer cancelled the contract and (before the expiry of the contract), revoked the cancellation, this process was also never recorded. Because only processing times in the mainframe system were recorded, it was barely known how long it took to process a specific process instance including the manual transport and sorting of mail and the sending of the response to the customer. Finally, the number of customer requests that had not yet been processed was also unknown.

In order to improve the situation, a project was initiated to integrate the available data sources into a consistent data warehouse for evaluation purposes. Furthermore, a concurrent workflow project was set up to create consistent process instance information from the arrival of a customer request until the completion of the process. This project was also instructed to analyze the integration of a planned workflow infrastructure with current and future enterprise controlling needs.

Workflow audit trail data contain information about the duration of activities and the participants who executed these activities. Using this information, the utilization of a specific resource for a specific activity/process instance can be computed. Given the fact that the monetary cost for the utilization of a resource is usually known (e. g. for human resources this is the hourly gross salary), the personnel cost for the execution of a single activity instance can be computed.

In order to put the results into a useable format, it is necessary to maintain the relationship between the workflow participants and the cost elements of the controlling structure of the enterprise (e. g. via a look-up table). Because personnel expenses account for a major share of the overall cost of the enterprise (as stated above), this use of audit-trail data lead to a more accurate and timely accounting of personnel expenses for specific activities or processes.

It should be noted that this bottom-up analysis of process usually leads to resource cost and utilization figures that are lower than the actual resource cost and utilization. This is due to the fact that many activities in an enterprise consists of non-workflow tasks, such as responding to incoming calls from a customer or paperwork for one-time processes, that are not worth implementing in a workflow application.

Therefore, if the analysis of audit trail data is to be used for the computation of future capacity requirements, the existence of non-workflow activities has to be taken into consideration. Furthermore, an activity-based costing framework should be accompanied by additional evaluations that take, for example, interest expenses (capital cost) and taxes into account (for a more detailed discussion refer to [10]).

However, the use of workflow audit trail data provides vital information for the purpose of activity-based costing. This way, an activity-based costing analysis can be performed at any time during the year, not only at fixed dates, depending on the availability of corporate balance sheets.

THREE PERSPECTIVES FOR PROCESS MONITORING AND CONTROLLING

Audit trail data can be used in a variety of evaluation methods. In order to reduce the complexity, which is related to process monitoring and controlling, it is useful to introduce different perspectives, to which these methods are related.

Useful classifications are:

- Process,
- Resource and
- Object perspectives

These are discussed in the following sections (an earlier version discussion of these perspectives can be found in [8]). Each perspective has its own purpose, but various interrelations exist between the three perspectives.

Process Perspective

Potential dimensions for an analysis in the process perspective are workflow models and activity models, both at the type and instance level. The process perspective is the core perspective of process monitoring and controlling. In this perspective, all key performance indicators related to the business processes are evaluated.

The evaluations in this perspective can be differentiated whether they concern time, cost or quality. For example, the timestamps recorded within the audit trail of a process can be aggregated to deliver the following facts about a workflow instance or (on an aggregated level) workflow type:

- Processing time of a specific workflow instance, which is computed as the difference between the completion time of a process and the instantiation time of a process.
- Average, maximum and minimum processing times of a workflow type, including the variance (the difference between longest and shortest instance, giving a distribution curve of processing times). It should be noted that in order to yield comparable results, only those workflow instances should be aggregated, where the same path of the workflow model has been processed (in case the workflow model contains alternative branches).
- Average, minimum and maximum processing times of specific activities (on the type level) and actual processing times (on the instance level).
- Transport times (the difference between the completion of one activity and the distribution of the next activity's work item to the participant's work lists).
- Idle times (the difference between the notification of participants about an executable activity and the starting time of this activity).

The evaluation of temporal information about the execution of workflow instances and types can lead to the identification of potential bottlenecks in the process design (e. g. if processing times of a specific activity tend to be longer than expected) as well as potential resource shortages (e. g. if idle times are long due to the unavailability of qualified participants).

Also, the analysis of workflow instances that lead to exceptions in the audit trail file (aborted instances, escalations) can be analyzed in order to identify error-prone process configurations. Corresponding reports can range from one specific process instance to different process aggregations. Additionally, learning curves can be used to show whether the process performance increases over time.

Information about the temporal behavior of a process can lead to a feedback into the original business process model and can be used for simulation purposes. An updated display of the average processing time visible to participants of each process instance can be used to forecast the estimated completion time of a process. However, this may lead to difficulties if a process contains many alternative branches. In the early stages of process executions, it may be hard to predict what will be the actual execution path of this specific process instance.

Resource Perspective

Though the design of efficient processes seems to dominate the current discussion regarding the state of the art design of companies' organizational structure, the isolated optimization of the process criteria is not the only objective. This easily could lead to a situation in which high process efficiency is accompanied by poor usage of available resources.

In other words: The customer might appreciate a short processing time, but the costs for this are not acceptable. In order to avoid such an isolated analysis, a framework for process monitoring and controlling has to include also a perspective that expresses the resource efficiency. As in the process perspective, the reports in this perspective analyze the costs, the time and the quality of the resources.

The costs of the involved resources can be derived from applications like asset management accounting. Because process monitoring and controlling usually deal with a subset of all processes, and the resources are, in the most cases, not 100 percent allocated to one process, only an appropriate part of the resource costs has to be taken into account.

The time dimension in the resource perspective reports on the availability of the resources. Comparable to the costs, only part of the resource capacity has to be analyzed which is required for the execution of the process. Key figures with regard to time include the average workload of a resource; processing times in relation to the same activity being processed by different participants as well as learning curves for specific activities and/or processes.

The quality of a resource can be measured in terms of good parts per 100s or 1000s (e. g. escalation-free activity executions), describing the efficiency of a resource, or the total output, measuring the effectiveness of a resource.

If resources with redundant functionality are available, the cost, time and quality indicators can be used within the role-based staff resolution. This way, an activity may request the cheapest/fastest/most effective resource that satisfies certain qualification criteria. This is another example for a feedback loop from the workflow controlling results to the design of the workflow application.

Object Perspective

Processes can be defined as the temporal and logical sequence of activities that are necessary to process a business object [11]. Examples of these objects are customer orders, production materials or invoices. Within a separated object perspective it is—in addition to the process and resource perspective—possible to define the processes' cost and value drivers.

Very often cause-effect relationships between the objects and the processes can be identified. Again, cost, time and quality criteria can be differentiated. Typical cost criteria would be the costs for the handling of an object. Elaborate approaches like activity-based costing can be used for the exact calculation of the costs and revenues belonging to an object. The typical processing time for a specific object type is another example for the use of temporal information. This data can be used, for example, for a more realistic sales forecast, estimating the processing time during negotiations with a potential customer. Finally, quality indicators illustrate potential problems related to an object.

As in the process and resource perspectives, the object perspective has a type and an instance level. On the instance level, a customer can be informed about the progress of a specific order. In this way, a specific object view gives access to the process perspective. Currently, logistics service providers are offering object-related information on the instance level within their web-based tracking systems. On the object type level, the outsourcing of objects can be discussed using aggregated data.

Various projects with retail companies demonstrated that the object perspective is of significant importance for the analysis of processes. In one case, for example, the object analysis was used to identify the complexity drivers in the invoice auditing process. On the basis of an individual workflow management system, the problem-creating invoices had to be identified.

Because the relevant department received more than 10,000 invoices monthly and had more than 140 employees participating in the invoice auditing process, this was a critical challenge. The process instances dealing with erroneous invoices were analyzed and related to the processed business objects. These objects were clustered into different groups after testing the significance of variables like the vendor, the goods received, or the involved staff member.

It turned out that the vendor was the best explanatory variable. Consequently, the costs created by these processes were mentioned during the next negotiation about delivery rebates with the suppliers. Figure 4 shows an example for a cluster analysis within the object perspective.

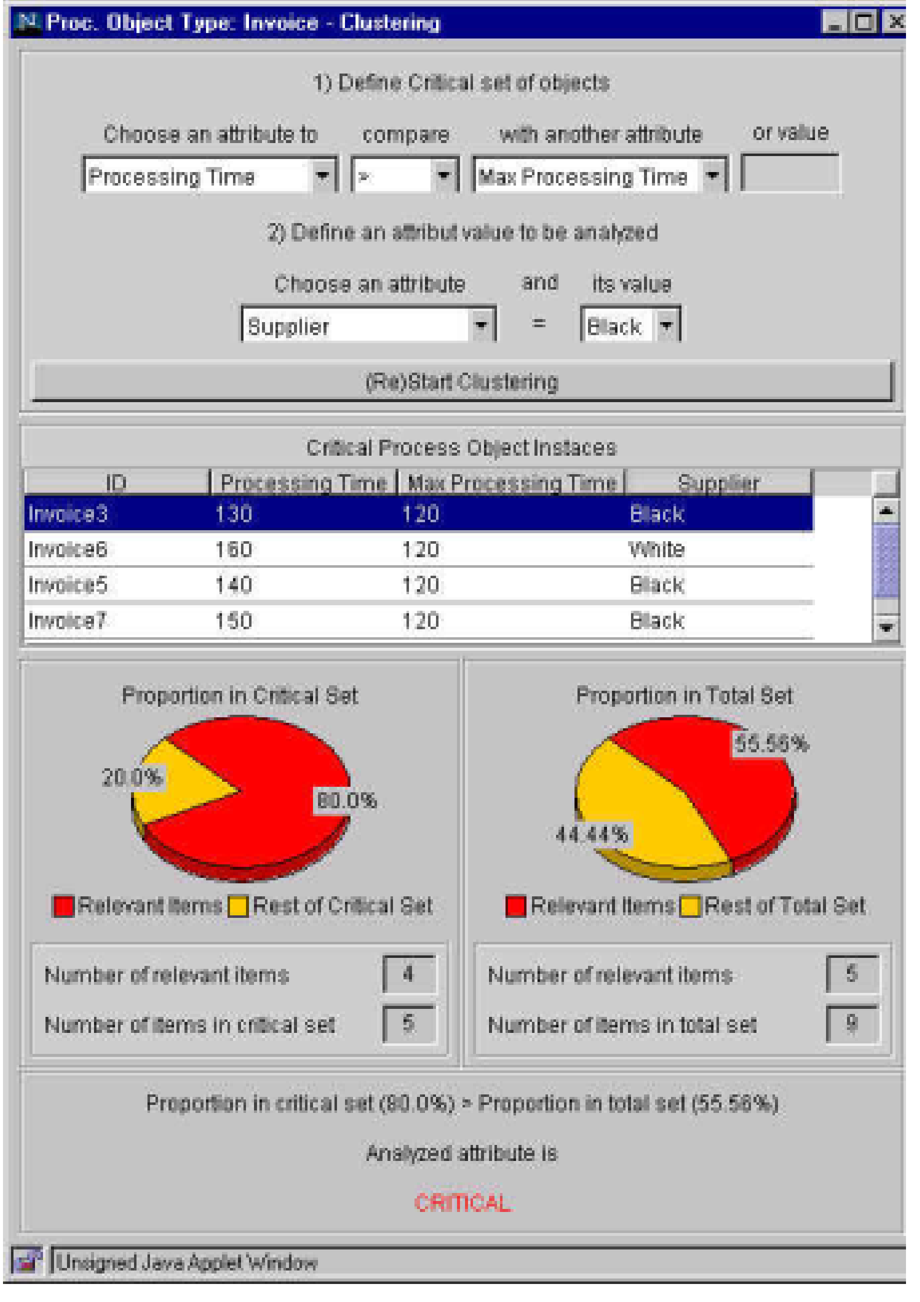


Figure 4: Cluster analysis within the object perspective

Other Evaluation Methods

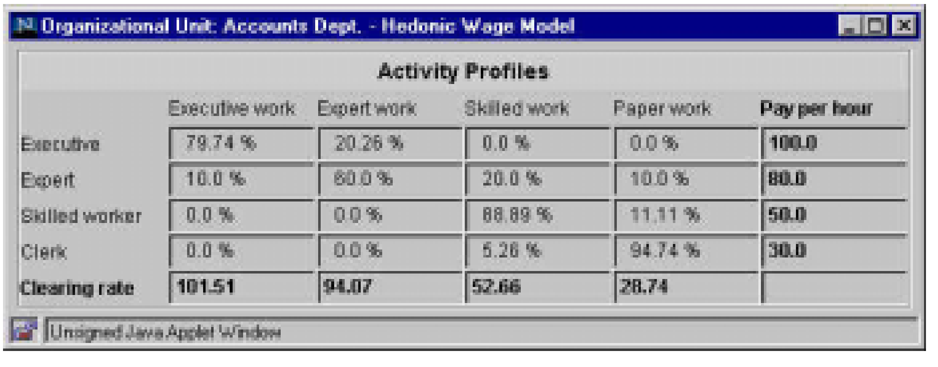
Various statistical techniques can be used within process monitoring and controlling. As an example, the cluster analysis within the object perspective was already mentioned. Another relevant evaluation technique is the statistical process control (SPC), which has been applied in production management systems for four decades.

SPC requires the definition of an upper and a lower level of tolerance referring, for example, to the expected processing time. Following the management-by-exception idea, the monitoring and controlling system informs the process owner if one value is above the upper or under the lower level. Another rule is that the process owner gets an early warning message, if n (with n usually >5) values are continuously increasing or decreasing.

A further interesting approach in the context of workflow-based process monitoring and controlling is the use of the hedonic wage model [12]. Originally designed to evaluate the improvement in the office area caused by new IT systems, the hedonic wage model can be easily adapted for process-related analysis.

This approach requires that it is known what class of employee (defined by salary) is doing what type of work (defined by degree of difficulty). Each class of employee is related to one class of activity. The assumption is that an employee should work only on activities for which s/he is qualified. For a given situation, the hedonic value can be derived through a system of equations in which the amount of work the different classes of employees are actually spending on different activities is summed up to the salary of this class of employees.

This leads to the hedonic value for each class of activity. These as-is-values can be compared with the desired to-be-models or the situation after reorganization. Figure 5 shows an exemplary hedonic wage model in a process-controlling tool.



Organizational Unit: Accounts Dept. - Hedonic Wage Model

Activity Profiles

	Executive work	Expert work	Skilled work	Paper work	Pay per hour
Executive	79.74 %	20.26 %	0.0 %	0.0 %	100.0
Expert	10.0 %	60.0 %	20.0 %	10.0 %	80.0
Skilled worker	0.0 %	0.0 %	88.89 %	11.11 %	50.0
Clerk	0.0 %	0.0 %	5.26 %	94.74 %	30.0
Clearing rate	101.51	94.07	52.66	28.74	

Unsigned Java Applet Window

Figure 6: Hedonic wage model

To date, a major disadvantage of the hedonic wage model is the time-consuming process of identifying who is actually doing what type of work.

The audit trail files of workflow management systems are an ideal support for the hedonic wage model. In order to implement this concept, every activity as well as every involved organizational unit has to be classified according to the criteria described above. Furthermore, both classifications cannot be used only for the hedonic wage model, but also for role-based staff resolution. These enhanced audit trail files can be used as direct input for a controlling tool implementing the hedonic wage model.

Related work

Workflow-based process controlling has received relatively little coverage in the related literature. Most publications in this area describe the technical facilities necessary for the logging of the audit trail data (cf. e. g. [13]). The Workflow Management Coalition Interface 5 specifies the elementary information a workflow management system should record the execution of workflow instances [14], but gives no advice on how to evaluate this information.

WEIKUM compares a temporal database approach for the storage of workflow runtime data with a text-file based approach in order to store the log entries [15].

The management of history data in distributed applications is discussed by KOKSAL et al. in the context of the distributed workflow management system Mariflow [5]. Technical issues for the storage of the data and economic queries on distributed data sources are presented, but no further discussion of the economic exploitation of the history data is given.

An approach for the tracking of history information in a distributed workflow management system is presented by MUTH et al. [16]. Within the prototype Mentor-lite, data about current and past workflow instances are kept in a temporal database that can be queried either at runtime or for ex-post analyses.

A methodology for the analysis of sequential design processes has been proposed by JOHNSON and BROCKMAN [17]. Their approach focuses mainly on the execution time of single process activities and is limited to sequential processes. However, one of the main optimization effects of workflow management systems is the concurrent execution of independent subtasks within one workflow.

Therefore, this approach is only applicable to a small subset of all workflow processes. A wider scope on the analysis of historical process data can be found in [3], where the author discusses the evaluation of workflow history data as workflow “metrics.” The controlling applications described are statistical evaluations as well as the runtime detection of late cases and overdue tasks.

All in all, the current work does not deal with process monitoring and controlling from a business and a technical viewpoint at the same time.

CONCLUSIONS

Today's enterprises focus on the identification and first-time optimization of processes, while the continuous evaluation and reengineering cycle has been implemented only in a small number of cases. This is caused in part by the lack of specialized process monitoring and controlling support tools. We have discussed the uses of workflow audit trail data within monitoring and controlling tools using the three perspectives process, resource and object.

The active feedback of evaluation data on the modeling of workflow processes is a promising candidate for further research. This closes the workflow-life-cycle and enables an active real-time-controlling, e. g. through the re-assignment of workflow activities based on a workflow analysis or through a knowledge-based redirection of workflow exceptions that delivers exceptions to more experienced resources first, before a member of the next level of hierarchy is notified.

Workflow-based process monitoring and controlling enables the evaluation of business processes with a higher quality of data than before and poses a promising field of development for management information system designers. It allows process analyses whose application had been impossible due to a lack of quality data, such as the hedonic wage model.

Nevertheless, although there are tempting technical opportunities, cultural and legal restrictions have to be taken into account, as well.

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