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# A HOLISTIC PROCESS PERFORMANCE ANALYSIS THROUGH A PERFORMANCE DATA WAREHOUSE

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## Abstract

*This paper describes how a performance data warehouse can be used to facilitate business process improvement that is based on holistic performance measurement. The feasibility study shows how management and analysis of performance data can be facilitated by a data warehouse approach. It is argued that many of the shortcomings of traditional measurement systems can be overcome with this performance data warehouse approach.*

## Introduction

In order to gain competitive advantage many companies have reengineered their processes during the last decade. This development was initiated by Hammer (1990), Davenport/Short (1990) and others. These authors argued that the competitiveness of a company depends to a large degree on the quality of its business processes. However, for gaining long-term advantage, it is not sufficient merely to reengineer the business processes. It is essential that the newly designed business processes are continuously improved. This concern was stated more clearly by Harrington: "Measurements are key. If you cannot measure it, you cannot control it. If you cannot control it, you cannot manage it. If you cannot manage it, you cannot improve it." (1991, p. 82).

A number of authors have criticized traditional performance measurement. For instance, Eccles (1991) argues that quality-oriented performance measures such as innovation or customer satisfaction are not an integral part of regular management reports, and that the very popular financial figures are the consequences of yesterday's decisions and not the indicators of tomorrow's performance.

In an empirical study, carried out at Fribourg University, we identified four main shortcomings of current performance measurement systems:

- Performance measurement is *focused too strongly on financial performance indicators*. A holistic performance measurement and assessment, as suggested by EFQM (2000) for instance, usually does not take place.
- *Business processes are not measured systematically*. Even those companies that have launched business process reengineering projects often neglect process performance measurement. Instead, measurement takes place at department or business unit level, but not at process level.
- Performance data becomes available with a considerable *time lag*. In many companies performance-relevant data is extracted from many different systems and it is not unusual that manual data handling is needed. If the degree of IT-integration is low this procedure is time-consuming, and performance reports will become available (too) late.
- *Access to performance data is complicated*. The underlying reasons are that the relevant data is dispersed over different functional units, and that performance data is stored in different formats (electronically, on paper). In addition, decentralized data management may lead to inconsistent data.

To overcome these shortcomings, we suggest the implementation of an IT system that stores and manages all performance-relevant data centrally; including both financial and non-financial data. This type of system is called a Performance Measurement

System (PMS). The conceptual aspects of PMSs have been discussed by Kueng (2000). The research question of this paper is the following: How can the requirements a PMS has to meet be implemented via an IT-based system?

## General Requirements of a Performance Measurement System

The main objective of a PMS is to provide comprehensive and timely information on the performance of a business. This information can be used to communicate goals and current performance of a business process directly to the process team, to improve resource allocation and process output in terms of quantity and quality, to give early warning signals, to make a diagnosis of the weaknesses of a business, to decide whether corrective actions are needed, and to assess the impact of actions taken.

To achieve these goals performance-relevant data is stored centrally in a database which is accessible for different categories of users, such as analysts, process owners, departmental managers, controllers, etc. As shown in Fig. 1. performance-relevant data is collected from various sources such as the different operational information systems (IS) that are in place; e.g. ISs that are used in the human resource department, production planning and control systems, ISs supporting the sale and distribution function, etc. In addition, company-external data, such as results from market research, may be included as well (Kueng et al., 2000).

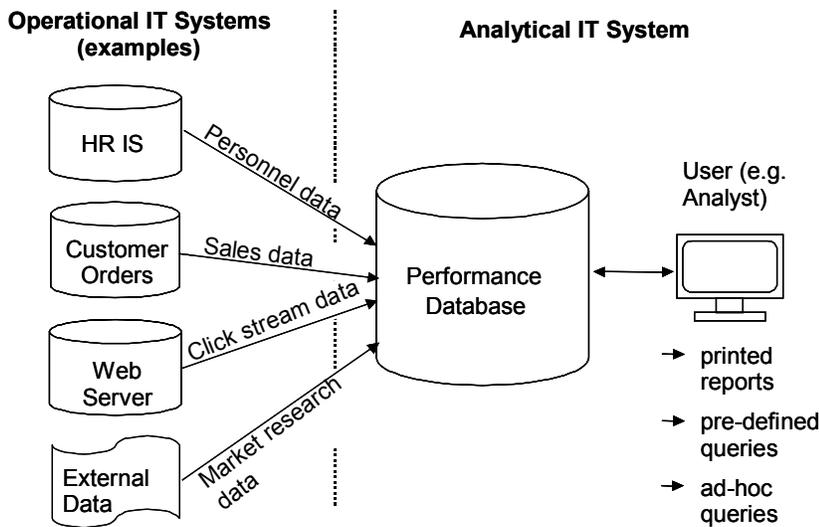


Figure 1. A Performance Database as a Central Point of Reference

A PMS should meet various requirements (Kueng, 1998). First of all, the system must be capable of tracking *both financial and non-financial performance indicators*. For instance, it must be possible to introduce the performance indicators that are needed to assess a company according to the EFQM framework (EFQM, 2000). Using a broad set of performance indicators requires the inclusion of *both company-internal and external indicators*. This in turn means that the PMS must be able to gather data from various sources (manual and electronic). The performance-relevant data collected must be *stored on non-volatile media* (e.g. a relational database) so that the data can be analyzed over a long period of time. Performance data stored in a PMS must be accessed by different levels of staff such as process owners or general managers. To lower the barriers to use, the system must be equipped with a *user-friendly interface*,

which will support, for example, an easy data selection mechanism, free choice of data aggregation levels, and any selection of attributes to compare. Moreover, *security features* must control access to the system; i.e. defining and checking which people have the right to see which data. Additionally, a PMS must take into consideration not only the level of current performance but also the *target values* for each performance indicator. The definition of target values increases the power of a measurement tool and it enhances its usability. Finally, a PMS must support the automated *dissemination of results*. For instance, a PMS should support the distribution of performance results via Intranet and it should make it possible to alert selected people (e.g. via email) if the value of certain performance indicators falls below a specified lower limit.

## Specific Requirements of a Performance Measurement System: An Example

In this section the data requirements of a PMS to be built for a particular company are described. In the following section, it will be shown how the requirements have been transformed into a running system.

When building a PMS we build on the work of Kueng (2000). He suggests starting with an organizational and goal analysis. This includes the definition of enterprise-wide objectives, the identification of the stakeholders, the business processes, and the description of the business process goals. This information is used to derive the appropriate performance indicators. But first the company is described, for which a PMS has been built.

**General Description of the Company**

The company belongs to the electronic and machinery industry, it is medium-sized and is divided into five business units; i.e. Assembling, Automotive, Components, Electroplating, and Plant Construction. Most goods are manufactured in a so-called ‘batch production’ style. The majority of goods are utilized (by its customers) as elements and units of larger products; e.g. automotive engineering. The number of orders carried out per year is about 20,000. Some of the goals the company wants to achieve are the following: (1) increase market share; (2) reduce cycle time; (3) lower stocks of raw material and semi-finished products; (4) increase turnover (sales revenue); (5) increase customer satisfaction.

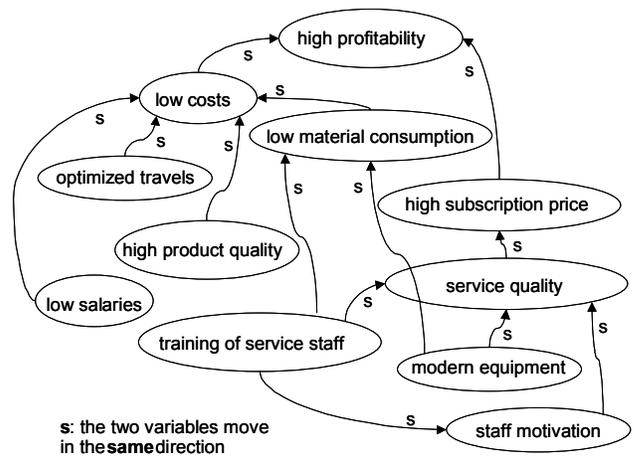
**The Two Main Business Processes of the Company**

The two business processes to be analyzed and improved via a PMS are the Sales Process and the Service Process. The Sales Process includes the following three activities: (1) negotiation, (2) delivery, (3) invoicing. The activity ‘negotiation’ includes negotiating price, delivery date and terms of payment. Within the activity ‘delivery’, the goods ordered are delivered to the customer and a delivery note is produced. The activity ‘invoicing’ includes the creation of an invoice, forwarding it to the customer, and entering it in the A/R system.

The Service Process consists of four activities: (1) taking a service order, (2) dispatching the order to service personnel, (3) repairing faulty equipment. Service orders are taken either by telephone or by fax. The service process is carried out about 12,000 times a year and the number of personnel engaged in this process is about 30.

**The Goals of the Business Processes and the Information Needs**

From the company goals—given above—business process-specific goals were derived, see Fig. 2. The overall goal of the Sales Process is ‘high profitability’. In order to achieve this goal the costs for carrying out the requested services (i.e. repairing faulty equipment) should be low. On the other hand, profitability can be increased via high subscription prices since most service orders are carried out on a subscription basis; individual billing is the exception rather than the rule. Low costs can be achieved, for instance, by low material consumption, and this in turn is supported by modern equipment. (For simplicity, Fig. 2 shows only those variables/relationships that move in the same direction.)



**Figure 2. Goal Network of the Service Process**

**The Information Needs of the Involved Roles**

The PMS to be created will be used by three categories of staff: general managers (i.e. heads of business units), process owners, and process participants (sometimes referred to as process actors). The general managers are mainly interested in financial and customer aspects. In particular they want to know the turnover (sales revenue) per business unit, and customer satisfaction per business unit and process. The process owners want to analyze cycle time, turnover, and customer satisfaction of their processes. The process participants want to know cycle time and customer satisfaction of the processes they are working for.

**Technical Requirements**

The technical requirements, given by the company, are the following: performance data should be stored on a widely used database such as Oracle™ or SQL Server™. The user interface—to access performance data and to run performance analyses—should be supported by a web browser.

## Management of Performance Data

The structure of the data for the continuous goal-oriented improvement of business processes is multidimensional. This follows from the user requirements, for instance: “Which customer group—obtaining services from the Service process—shows the most significant reduction of satisfaction over time?” Fig. 3 represents the relevant dimensions in the above question.

We now have to determine a robust architecture that meets the requirements mentioned above. One option would be to access and manage the relevant data on the operational IT systems and not maintaining a separate database as suggested in Fig. 1. This solution was not considered useful, because (1) the data in the transactional systems is not stored in the way the users need it in order to analyze business and support decisions. (2) The response time is unsatisfactory because complex processing and preparation of data is needed. (3) If various data sources are taken into account the complexity rises considerably. Another possibility – proposed by Kueng et al. (2000) and List et al. (2000) – would be to maintain a separate database. This is consistent with the definition of a data warehouse suggested by Inmon (1996, p. 33): “A Data Warehouse is a *subject oriented, integrated, non-volatile, and time-variant* collection of data in support of management’s decisions.”

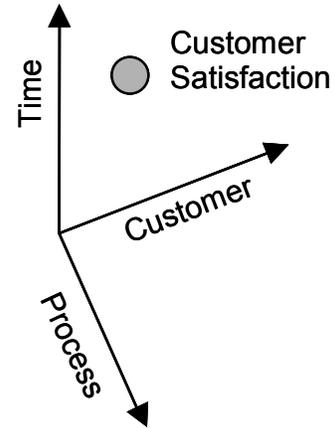


Figure 3. Multidimensional Structure of Indicators

## Design of the Performance Data Warehouse

The semantic data model of a data warehouse can be created either in a relational or a multidimensional way. While the relational model supports storage of data with minimal redundancy, the multidimensional model tries to generate a data model which optimizes future user demands. For the project presented we chose the multidimensional structure.

For the construction of the semantic data models for multidimensional data structures, both researchers and practitioners have developed a number of concepts. For instance, there are proposals that are rooted in the classical Entity-Relationship Model and propositions that are based on the object-oriented concept. In addition, further notations have been suggested by Bulos (1996), IBM (1998) and others. After examining these approaches we decided to apply the ADAPT (Application Design for Analytical Processing Technologies) approach of Bulos. The reasons that lead us to this decision are the following, cf. Totok/Jaworski (1998): (1) ADAPT has been used in several projects successfully. (2) The approach has been well accepted by people involved in the projects. (3) The powerfulness of expression of ADAPT is considerable. Even though we have emphasized the positive aspects of ADAPT we do recognize some shortcomings: (1) By omitting clear separation of the semantic and logical design levels, performance relevant decisions are anticipated. (2) The powerfulness of expression mentioned above requires a major learning effort of data warehouse designers.

The basic elements of ADAPT are *cubes*, *dimensions*, and *formulas*, see Fig. 4. Measures (i.e. the indicators to be measured) represent a particular kind of dimension—a measure dimension. Fig. 4 shows a part of the process performance data model used for the company described in the previous section. In the center the cubes *Duration*, *Customer Satisfaction* and *Turnover* are shown. Each cube has its own measure dimension, e.g. cycle time for cube duration. The measure dimension for *Customer Satisfaction* consists of three single measures: *Expectation*, *Perception* and *Performance Gap*—this third measure is calculated by a formula. Furthermore, the cubes are attached to their related dimensions. For instance, the cube *Turnover* has the dimensions *Organization*, *Customer*, *Process* and *Time*. As shown on the *Process* dimension several hierarchies can be built (for instance *Process hierarchy* and *Business Unit hierarchy*). For each hierarchy the aggregation path is shown (for instance *Activity*, *Process* and *Business Unit*). Starting from the bottom element the two arrows point to the next higher aggregation level.

In the next step the conceptual data model (Fig. 4) was implemented physically with a Star Schema Architecture on the Microsoft SQL Server 2000™. As OLAP-Clients we used both the Analysis Manager™ from Microsoft and the OLAP-Client from Microstrategy™.

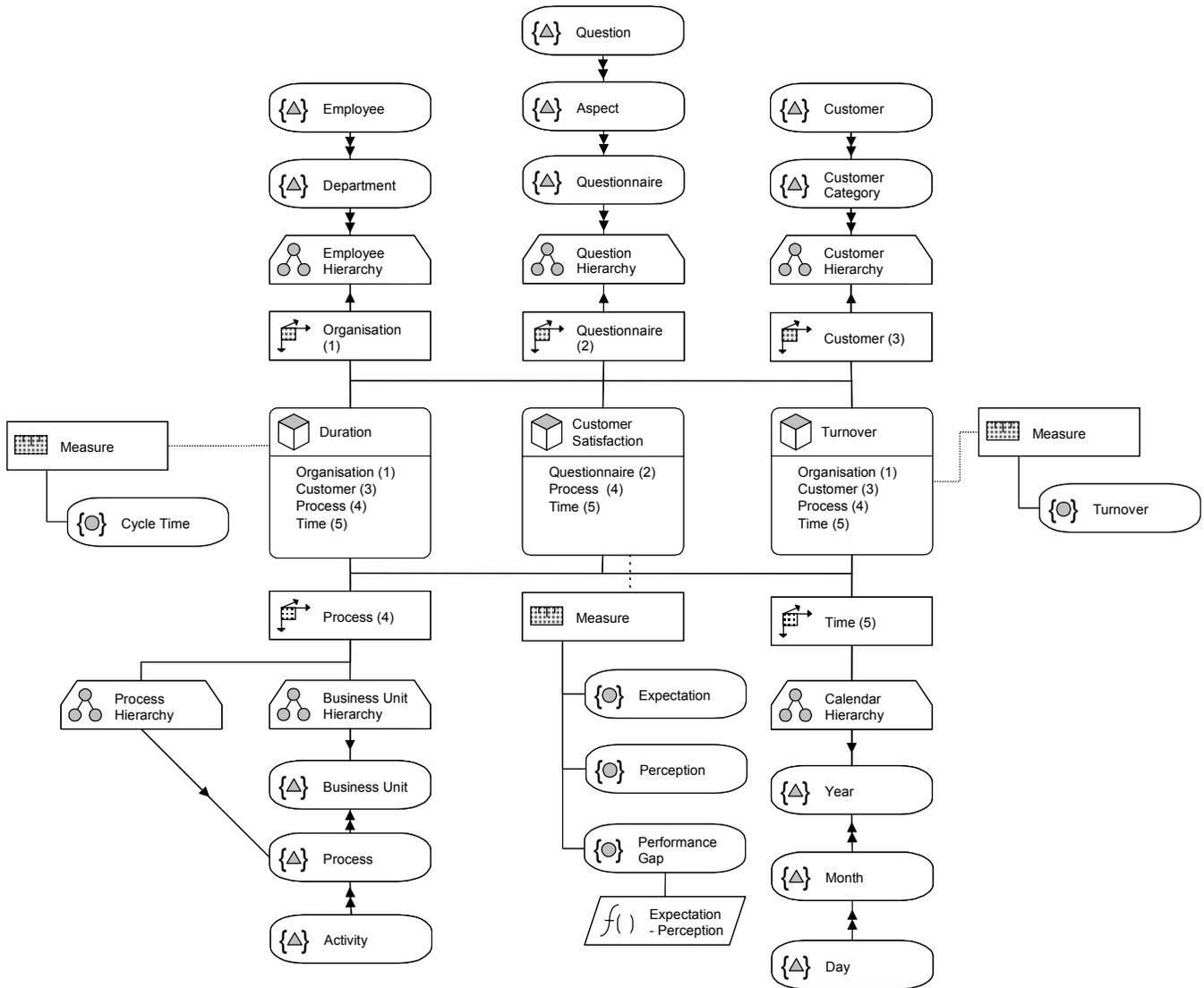


Figure 4. Conceptual Design of the Process Data Warehouse in ADAPT Notation

## How the Information Needs Can Be Satisfied

In the last section we described the multi-dimensional data model for the measures to be monitored. In this section we show how the cubes have been implemented in our performance measurement system. The design of the IT-based system results from the requirements discussed at the beginning of the paper.

As shown in Fig. 5 two databases are used in our example: on the one hand a relational data warehouse, managed by the Analysis Manager™, that stores the measures related with the dimensions, on the other hand, a database that stores auxiliary data. The latter describes the following entities: (1) Organization: employees, departments, business processes, business units and their manager. (2) Goal tree: primary goals of the organization and the derived goals for the corresponding organizational entities and their specification by measures. (3) Access rights for the performance data and the auxiliary data.

Goals are deliberately formulated at a company as well as at a process level for a number of aspects in order to counteract the demonstrated weaknesses of traditional financial-oriented reporting. Fig. 6 shows the user interface of the PMS built. The following aspects (views) are taken into account: Financial, Customer, Employee, Development and Environment. For each aspect

one or more goals were defined at process level (i.e. for the Service Process in this example). The individual goals are specified by Key Performance Indicators (KPI). For each indicator the target and the actual performance are shown. The actual performance is determined by a query to the performance data warehouse. On the basis of a comparison of the target value and the actual performance, the performance gap is calculated and represented by 'traffic lights', see column 'status' in Fig. 6.

Which deviation leads to which status? The user interface of the system allows users to define this information for each KPI. Moreover there is the possibility to inform the person in charge by a push- principle in case of major deviation. Technically, this is realized by alerts handled by the Analysis Manager™, which sends an email when the defined conditions are met. In case of an unplanned development of a performance indicator the process manager may inspect the details directly. As in traditional Management Information Systems, the user views the details of the data which help to determine the causes of the deviation, see Fig. 7. Additionally, there is the possibility of navigating (drill, slice and dice) freely through the performance data by means of the OLAP-Client. Restrictions are defined by user access rights and the dimensions put in place.

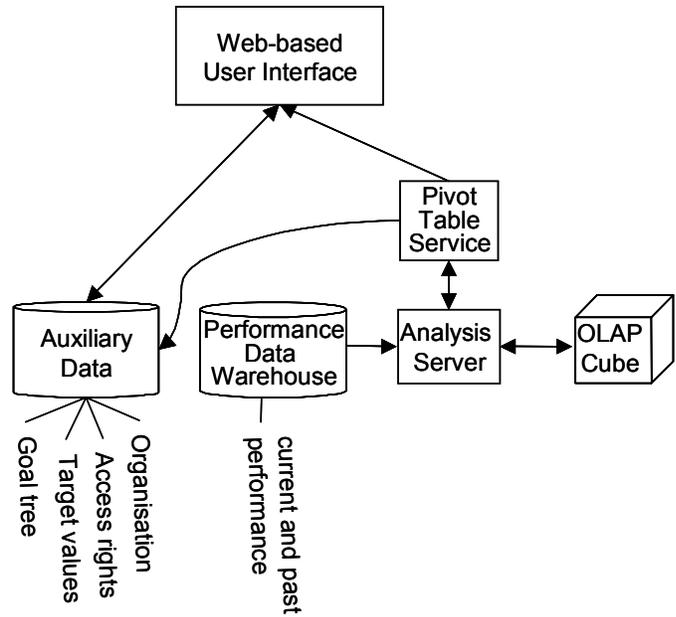


Figure 5. Architecture of the Performance DWH

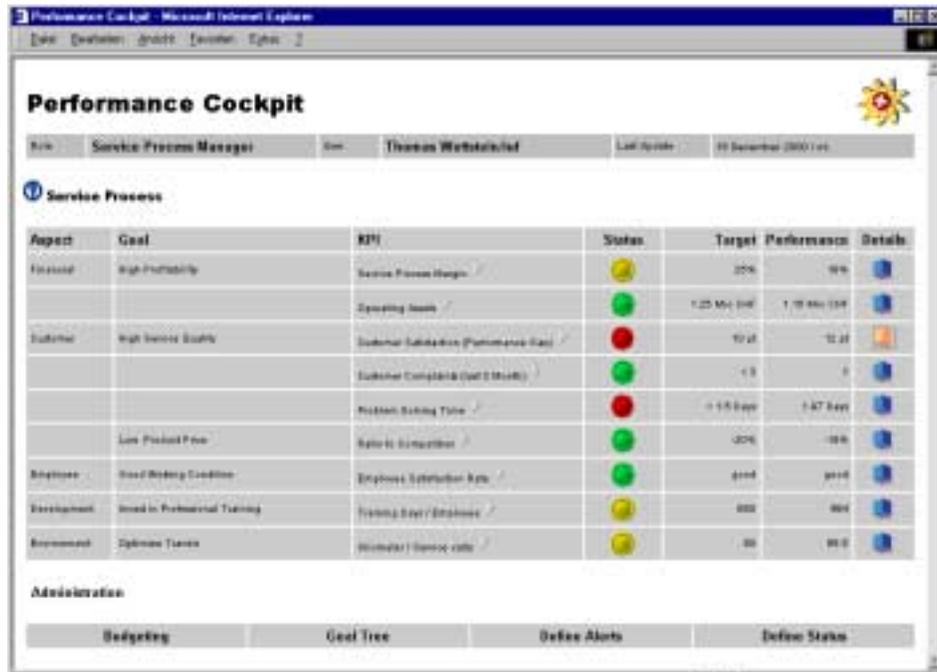


Figure 6. A User Friendly Interface That Offers a Holistic View of the Processes



Figure 7. Drill-Down Facility to Analyze the Roots of an Unsatisfactory Performance (cf. Fig. 6, 3<sup>rd</sup> row)

trail data of a workflow management system (e.g. MQ Series™ from IBM) and uses process definition data generated by a process modeling tool (e.g. ARIS Toolset™). Workflow audit trail data is imported into a read-only relational database and is stored on workflow instance state level, whereas the ARIS database is accessed during process analysis via ODBC. The current (third) version of PISA offers a web-based interface and runs on a client-server architecture. The performance indicators that can be analyzed are time- and frequency-based. For instance, the tool shows the average cycle time of processes or work time of process actors. The shortcomings of PISA are the following: (1) it takes into account audit trail data from workflow management systems but does not include performance-relevant data from other operational IT systems; (2) the performance (response time) of the system is limited; (3) flexibility in analyzing a given process is limited.

PPM™ (Process Performance Manager) is a tool that has been developed at IDS Scheer AG, Germany (cf. www.ids-scheer.com/ppm). The tool collects the performance-relevant data mainly from SAP's R/3™ modules. PPM calculates predefined performance indicators at different aggregation levels and stores them in a relational database. A web-based interface provides access to the users, of which three main groups can be defined: operations-level employees, middle management and executive management. Some typical performance indicators offered by PPM are 'process cycle time', 'processing frequencies', 'schedule compliance', 'number of users', or 'number of participating units'. The main drawbacks of the tool are: (1) data sources are focused on SAP's product range; (2) performance indicators are limited to time-based aspects and frequencies.

PRO Measure™ and PRO Manager™ (cf. www.img.com/pmb) are tools that were jointly developed by the company IMG and the University of St Gallen a few years ago. PRO Measure™ extracts data from R/3™ modules such as Procurement, Inventory Management, and Sales & Distribution. PRO Manager™ uses the extracted raw data and computes values for various performance indicators related to the supply chain. The tool is based on MS Excel™ (using Pivot Tables) and enables ad-hoc analyses at different aggregation levels. The performance indicators reported include for example 'volumes', 'service level', 'on-time deliveries' and 'cycle time'. The limitations of the tool package are twofold: firstly, data sources are limited to a few R/3™ modules; secondly, performance indicators are limited to time-based aspects and frequencies.

## Related Work

Business processes analysis and controlling have received little attention from either research or industry. Only a small number of prototypes and products have been implemented or are commercially available.

In the PROMOSYS (Process Monitoring System) project a process performance measurement system was implemented in the finance department of a large company (Kueng, 1988). This system collects data—on a monthly basis—from an R/2™ system (from SAP), carries out some data transformations and stores the performance data in EIS™ (from SAP) which runs on a midrange system. The users (e.g. process owner) access the performance data via inSight™ (from arcplan). Examples of the performance indicators controlled were 'percentage of payment on time', 'costs of outstanding money' and 'risk coverage'. The dimensions to be analyzed were time, regions, and products to mention a few. The main shortcoming of the system is that only one data source (i.e. R/2) is taken into consideration and, therefore, a holistic performance analysis is not given. Another weakness is the limited flexibility in querying the database.

PISA (Process Information System with Access) is a process analysis tool developed at the University of Münster, Germany (zur Muehlen/Rosemann, 2000). PISA evaluates audit

There is common understanding that performance should be measured from various perspectives. This in turn means that (1) performance measurement systems should consider different data sources, and (2) that performance indicators must be defined on the basis of the company strategy. However, the analysis above shows that today's measurement tools are focused on one type of data source (e.g. workflow systems, ERP systems) and that performance indicators cannot be defined freely to support the company strategy. The probable cause of this shortcoming is that most performance measurement tools have been developed from a technical perspective—and not from a business perspective.

## Conclusion

It has been shown that a holistic process performance analysis requires performance-relevant data from various operational IT systems such as workflow systems or ERP systems. Through the combination of the multiple data sources a multidimensional assessment of process performance can be achieved. The approach to extracting data from different operational IT systems and to storing it in a performance data warehouse was successful. In particular, the performance data warehouse approach offers enhanced analysis features such as the execution of ad-hoc analyses along different dimensions (e.g. time dimension, process dimension, business unit dimension) and aggregation levels. Those multidimensional analysis capabilities, which are not restricted to time-based figures, may offer new insights to the process owners and other associated roles. In addition, the performance data warehouse approach enables the use of different analysis and reporting tools. In our example, we used the analysis tools of MS SQL Server 2000™ and Microstrategy™, but other tools could be employed instead. Both tools facilitate the creation of web-based user interfaces, and this in turn, lowers the barriers of managers against the adoption of a new performance measurement system. All in all, we believe that the performance data warehouse approach represents a step forward towards a sound and integrated process view which in turn represents a prerequisite to improve business processes on a continuous basis.

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