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ENABLING TECHNOLOGIES FOR SUPPLY CHAIN PROCESS MANAGEMENT

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Abstract

Supply chain management deals with the efficient coordination of enterprises along a value chain to provide goods and services to end users. While the operational and strategic aspects of supply chain management have been researched to some extent, one of the questions for enterprises is the management and controlling of supply chain operations on a tactical level. We discuss the activities on this level and show the impact of information availability on the operational management of the supply chain. Using the framework of the Balanced Scorecard, we introduce the Supply Chain Scorecard as a suitable tool for the controlling of supply chain operations on a higher level of abstraction.

1 Motivation

The provision of goods and services to consumers and the reverse flow of used goods create a network of organizations that needs to be coordinated in order to function efficiently. While enterprise management functions are focused on a single organization, the management of supply chains extends this view to cover neighboring enterprises, up to the supply chain in its entirety. In order to support this widened scope in an efficient manner, an IT support system is required that provides supply chain managers with relevant information. Depending on the timeframe of the managerial activities and the frequency with which they occur, strategic, tactical, and operational levels of supply chain management can be distinguished [13]. These levels have different information needs.

The *strategic level* of supply chain management (SCM) is characterized by the management of relationships between the participating organizations of the supply chain. Establishing supply chain networks as well as forming strategic partnerships and joint market strategies are major tasks that are performed at this level. Agreements about information interchange that are negotiated at this level have a direct impact on the performance of the supply chain as a whole. In section 3 we outline the benefit of information availability within the supply chain.

The *tactical level* of supply chain management covers the planning of supplies, manufacturing schedules, and the forecasting of demand. The major task at this level is to ensure the seamless operation of the supply chain across the enterprises involved. We discuss the relevant information for this level as well as tool support using the supply chain scorecard (SC^2) in section 4.

The *operational level* of supply chain management focuses on day-to-day operations within the independent organizations and the interaction between them. Information requirements at this level include live updates about ongoing supply chain process instances, metrics about the operational activities within the supply chain as well as notifications in the event of errors. In section 5 we show how an integrated process-oriented infrastructure can help obtain information for both, the operational and tactical level of supply chain management.

2 Related Work

The goals of supply chain management are design, operation and maintenance of integrated value chains to satisfy consumer needs in the most efficient way by simultaneously maximizing customer service (see e.g. [4], [9], [18]). Today, SCM is accepted as a concept integrating inter-organizational business processes and comprises other concepts such as Efficient Consumer Response, Quick Response, Continuous Replenishment and Customer Relationship Management [1]. The design of supply chains requires the specification of business processes and supply chain wide planning routines as special task of the development of information systems as the backbone of any supply chain integration. Information technology is widely perceived as the enabler of supply chain integration ([1], [9]). Enterprises participating as partners in a supply chain have to provide their activities in a way that maximizes the supply chain efficiency. Thus, they have to concentrate on their core competencies [4].

The Supply Chain Operations Reference (SCOR) Model provided by the SUPPLY CHAIN COUNCIL specifies inter-organizational business processes and their information flows [19]. The SCOR Model contains measures for operational control and best practices of supply chain design. There are five main processes characterizing the SCOR Model: Plan, Source, Make, Deliver and Return. The SCOR Model is organized in four hierarchical levels as shown in Figure 1. The main processes are defined on the top level (level one). On the second level these main processes are clustered into process categories depending on the underlying process model. There are three relevant business categories of the SCOR Model on this level, which are "Make-to-Stock", "Make-to-Order", and "Engineer-to-Order". Additionally, on level two some enabling processes are identified.

The highest level of detail within the SCOR Model is the third level where every process category of level two is refined by inter-related process elements such as the ones shown in the lower right part of figure 1. The processes and their relationships are defined using tables. The lower left of the figure shows an example for the definition of the process step “Schedule Product Deliveries”.

Level four is not covered by the SCOR Model since it would contain the detailed description of the internal business processes of the cooperating enterprises. The SCOR Model is a reference model for structure, processes, and information flow within an inter-organizational supply chain. As a result, the SCOR model needs to be extended with a framework for the adjustment of internal and external business processes in order to align an existing process infrastructure with the inter-organizational processes that are the result of a SCOR approach.

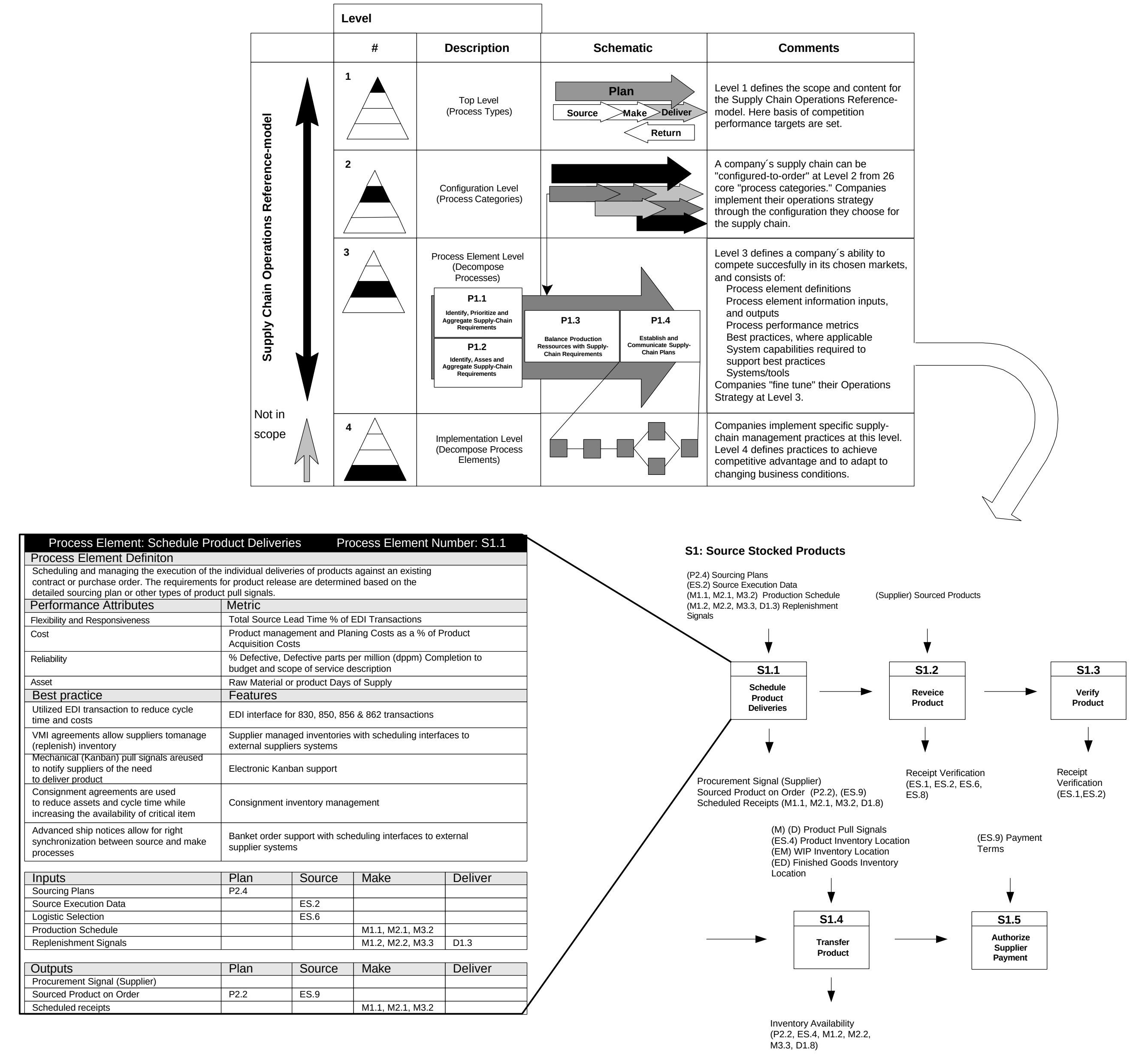

Figure 1: Organization of the SCOR Model [19]

Parallel to the SCOR model, several standardization initiatives have published documents that focus on the design of supply chain processes. The ROSETTANET consortium, for example, is a non-profit group of more than 400 companies in the information technology and electronics domain which aims at standardizing the trading networks between these companies by providing standards for business documents (e.g. purchase orders) as well as so-called partner interface processes (PIPs), which define process interaction between trading partners (e.g. acknowledgement of receipt etc.) [17].

An early report on process-oriented controlling was provided by MCLELLAN [15]. He gives an overview of the analysis of historical process data and discusses the evaluation of workflow history data as workflow metrics. The controlling applications described are statistical evaluations as well as the run-time detection of late cases and overdue tasks.

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3 The Impact of Information Availability on Supply Chain Management

Several studies have shown that there is a positive effect of information sharing along the supply chain. In [3], [7], and [14] several authors have estimated savings in an information sharing supply chain using simulation models. The focus of this chapter is not to quantify the effect of information sharing along supply chains and thus proofing the effect, but to presume a positive effect and give simple model-based explanations for it.

The integration level of material and inventory management and the structure of order costs are the main parameters of supply chain management [4]. We illustrate this using a simple model of inventory development and the effects of an integrated material and inventory management on order costs (see figure 2) [2]. Three variables are relevant to calculate the economic ordering quantity, which are warehousing costs, costs per unit, and costs per order. For simplicity reasons the costs per unit are assumed to be constant (the results were the same if discounts on certain order sizes were taken into consideration). Warehousing costs increase linearly with an increase in ordering quantity since they are directly bound to the inventory level. The cost per order decreases with an increasing order size because fixed costs are allocated among more units. The total cost function is the sum of these three functions as shown in the top left model of figure 2.

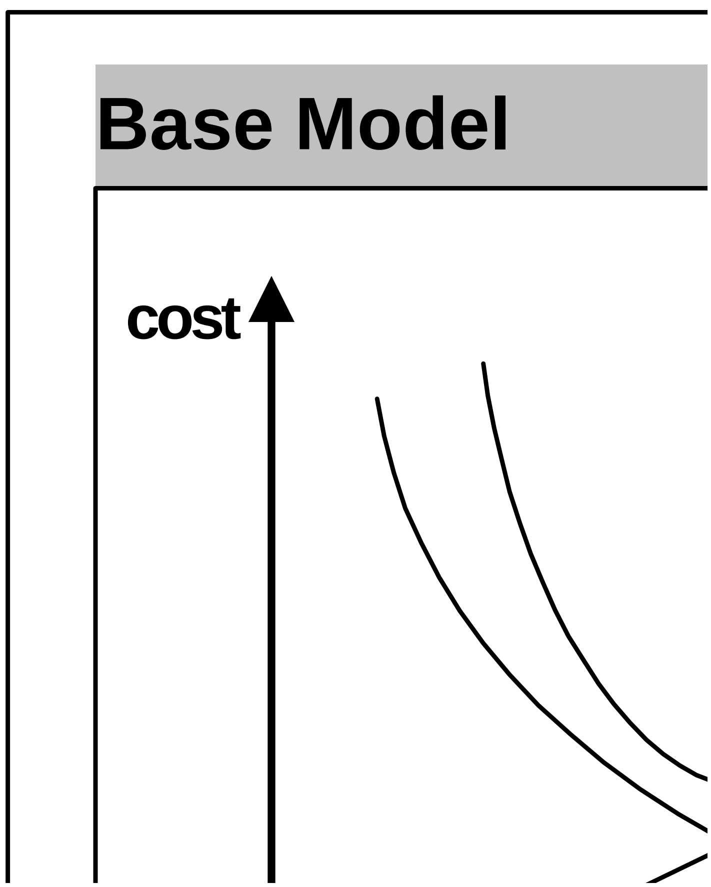

Figure 2: **Effects of information availability on material and inventory management and ordering costs**

The development of inventory over time is shown in the top right model of figure 2. A certain safety stock is required to guarantee production in cases of supply shortages. In the beginning we assume a stock above this level. Furthermore, we assume a linear consumption function over time. Based on a given delivery time we can determine the reorder point for the economic ordering quantity.

It is important to understand that information itself never has a direct value for business. There are always indirect effects of information on business. Two of the relevant effects of improved information availability for the management of supply chain processes can be explained using the simple model introduced:

1. Information availability enables an enterprise to reduce the average stock level by reducing safety stocks and delivery times.
2. Information availability enables an enterprise to reduce the average stock level by increasing order frequencies.

Using information correctly ensures that required materials can be delivered on time. This effect is simply based on the exchange of information between partners along the business process (compare the center model of figure 2). If production planning systems of manufacturers and scheduling systems of suppliers are automatically provided with point of sale information of the retail partner, planning tasks can be performed with a higher quality. The result is a reduction of delivery times since this time is not only the shipment time but additionally the time used to organize the entire business transaction, which can be decreased dramatically. The effects discussed so far clearly argue for an integrated material management.

The second effect is based on the duration of contracts between supply chain partners. Based on long term agreements the costs per order can be reduced, because some uncertainty for suppliers and manufacturers is eliminated. In the simple model introduced in figure 2 this results in a left shift of the total cost function and a reduced minimum of the economic order quantity (compare bottom left model of figure 2). This implicates an increase in order frequencies which is economically reasonable (compare bottom right model of figure 2). To benefit from this effect, which lead to a reduced average inventory level because of reduced order sizes, an integration of material and finance management is necessary [10].

4 Tools for Supply Chain Process Management

4.1 Process Life Cycle

The efficient implementation of business processes following a process model is a key factor for the successful deployment of supply chain operations. Development, design and enactment of business processes form a life cycle that has been described by several authors as a closed loop (see e.g. [6]). Figure 3 shows such a life-cycle starting with the definition of the business process to be implemented followed by the implementation of the process model. The enactment of the process delivers run-time data of processed instances which can be passed on to a process monitoring phase where running process instances are surveyed. Data collected during the execution of the business processes, so-called audit data, is fed back to an ex-post analysis of process instances, which then generates information for the process redesign phase.

While the definition, modeling and enactment of supply chain processes is well understood, less documents can be found that deal with analysis and business intelligence aspects of supply chain processes. According to the life cycle described above, two kinds of process analysis can be distinguished: process monitoring and process controlling.

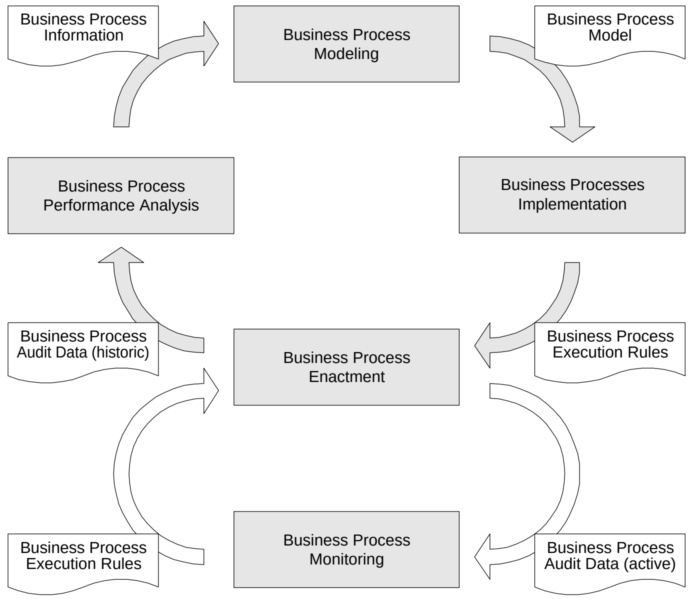

Figure 3: Business Process Lifecycle

4.2 From Process Monitoring to Supply Chain Monitoring

Process monitoring deals with the supervision and analysis of process instances at run-time [20]. Using monitoring information, administrators and process managers can adjust the behavior of current process instances and react to problems that arise during process enactment. Furthermore, process monitoring can be used to improve the responsiveness of an organization to customer inquiries. When the current state of a process instance can be automatically tracked, questions such as "Who is handling purchase order 0815?" can be answered in an efficient manner.

The analysis of current processes in the supply chain is a task of operational supply chain management, as described in section 1. Using a formal process definition as the framework for analysis, managers are enabled to detect deviations from agreed-upon process paths as well as differences in material or financial flows.

Since monitoring activities are performed in real-time an automated system is necessary that collects relevant monitoring metrics across the entire supply chain (inter-organizational monitoring) and merges this information with detailed monitoring data from the business processes of the individual organizations (intra-organizational monitoring).

4.3 From Process Controlling to Supply Chain Controlling

Process controlling deals with the ex-post analysis of business process audit data [20]. The analysis can either be performed at the instance level, or single process instances can be aggregated according to different criteria. Process controlling is useful for the evaluation of existing process models often resulting in process remodeling. Thus, its effects are more fundamental than the results of process monitoring.

Supply chain controlling is based on traditional process controlling, but it extends the scope of the business processes to the entire supply chain. Thus, supply chain controlling can be accomplished using the same methods as for process controlling adapted to the needs of inter-organizational cooperation. One instrument for process controlling is data warehousing. A data warehouse can be used to store materialized views on business processes to support the management's information requirements ([11]). OLAP operations can be applied to a data warehouse supporting different views on the supply chain eventually hiding the complexity of the entire supply chain [5].

To support hierarchical supply chain controlling, the structure of controlling information in the data warehouse has to be defined. Using hierarchical process designs as a source of the audit trail data and assigning cost information to single activities the idea of OLAP can be applied to entire supply chains. The fact table of the data warehouse then consists of single process instances with time stamps and assigned resources as key attributes as well as assigned metrics. Hierarchies are defined in lookup tables regardless of the data warehouse scheme employed.

4.4 Using the Supply Chain Scorecard (SC^2) as a Controlling Tool

The balanced scorecard was developed by KAPLAN and NORTON as a tool to support the implementation and measurement of strategic goals within an enterprise [12]. It consists of four perspectives each of which contains a distinct set of outcome measures (lag indicators) and performance drivers (lead indicators). The financial perspective covers the core measures of a corporation's financial success, such as return on capital employed or certain cash-flow indicators. The process perspective contains indicators from the internal business processes of the company in question, for example error rates, turnover times, or resource utilization. The customer perspective contains information about the market segments and customers of the company. The learning and growth perspective deals with objectives and measures for organizational learning and knowledge management. Depending on organization, domain and market, different implementations of the balanced scorecard can be found in practice.

Based on the ideas of the balanced scorecard the concept of supply chain scorecard (SC^2) is introduced to organize the required management perspectives for supply chain process management. The supply chain scorecard is based on the usage and structure of measures and performance indicators. In this paper we outline the use of the perspectives SC^2-Processes and SC^2-Finance.

The *process perspective* contains measures with regard to material management and process performance. Central measures are material turn over rates and stock cycles as average time of coverage. The use of time- and value based metrics from the local processes of the participant enables the forecasting of delivery times along the supply chain, which can increase customer satisfaction for build-to-order scenarios. Using process metrics, organizations are able to pass on "early warning" data about early or late shipments, allowing for a better resource allocation and seamless transitions between the local processes.

The *financial perspective* of the SC^2 contains financial metrics and indicators relevant to the supply chain as a global process. A cash return from investments is important to both, the supply chain as a whole and the individual participants. Cash Flow Cycles (CFC) are designed to monitor this information. A CFC is defined as the average time of payment given to pay for suppliers' services and goods. In order to integrate material and finance management the CFC needs to be linked to the material flows within the supply chain, since no financing should be required within the supply chain. Financing requirements would ultimately lead to higher consumer prices. Therefore, CFC indicators are important measures of the finance perspective and should be related to measures of the process perspective.

A useful measure is the Cash Flow Cycle Rate (CFCR) which is defined as the relation between the Cash Flow Cycle and the Stock Cycle. The CFCR should be always larger than 1, which implies that goods are being sold faster than they are paid for. It is crucial that the CFC Rates are not only considered for local partners but also for the supply chain as a whole. This in fact mandates that financial conditions have to be integrated virtually across the supply chain.

5 An Architectural Framework for Supply Chain Process Management

Supply chain controlling requires the integration of inter-organizational data into one global information repository for the supply chain. In addition, intra-organizational metrics need to be published to the participants in order to streamline operations along the supply chain. Since the technology landscape in today's companies is heterogeneous an integration layer is necessary to retrieve monitoring and controlling data. Enterprise Application Integration (EAI) vendors as well as workflow suppliers are enhancing their products with features to integrate components across different enterprises. Figure 4 shows an architectural framework for supply chain controlling applications.

The integration of corporate information systems for the operational enactment of supply chain processes can be achieved using messaging mechanisms or EAI middleware, depending on the existing infrastructure. While currently a large number of interoperability standards exists, a consolidation of the number of standards is very likely. Approaches such as SOAP, ebXML, ROSETTANET and WSDL have found widespread acceptance and form a complementing framework of XML standards for inter-organizational messaging applications. While the operational aspects of business-to-business interactions are quite well defined, the generation of analytical data from the operational processes is lacking a standardized foundation. Therefore, we propose the use of established data warehousing architectures and tools to collect supply chain monitoring and controlling information.

The integration of both, local and global information sources can be achieved using traditional integration concepts based on extraction, transformation and loading (ETL) tools. While the existing infrastructure of an individual organization is barely touched, certain organizational constraints have to be considered. Since supply chain controlling information is published to all enterprises involved, privacy and confidentiality concerns have to be addressed. Especially the sharing of internal cost data among supply chain participants is most probably a critical issue. In order to address concerns of this sort, a refined access control structure for supply chain managers as well as storage and usage of supply chain monitoring and controlling data need to be negotiated among the participants.

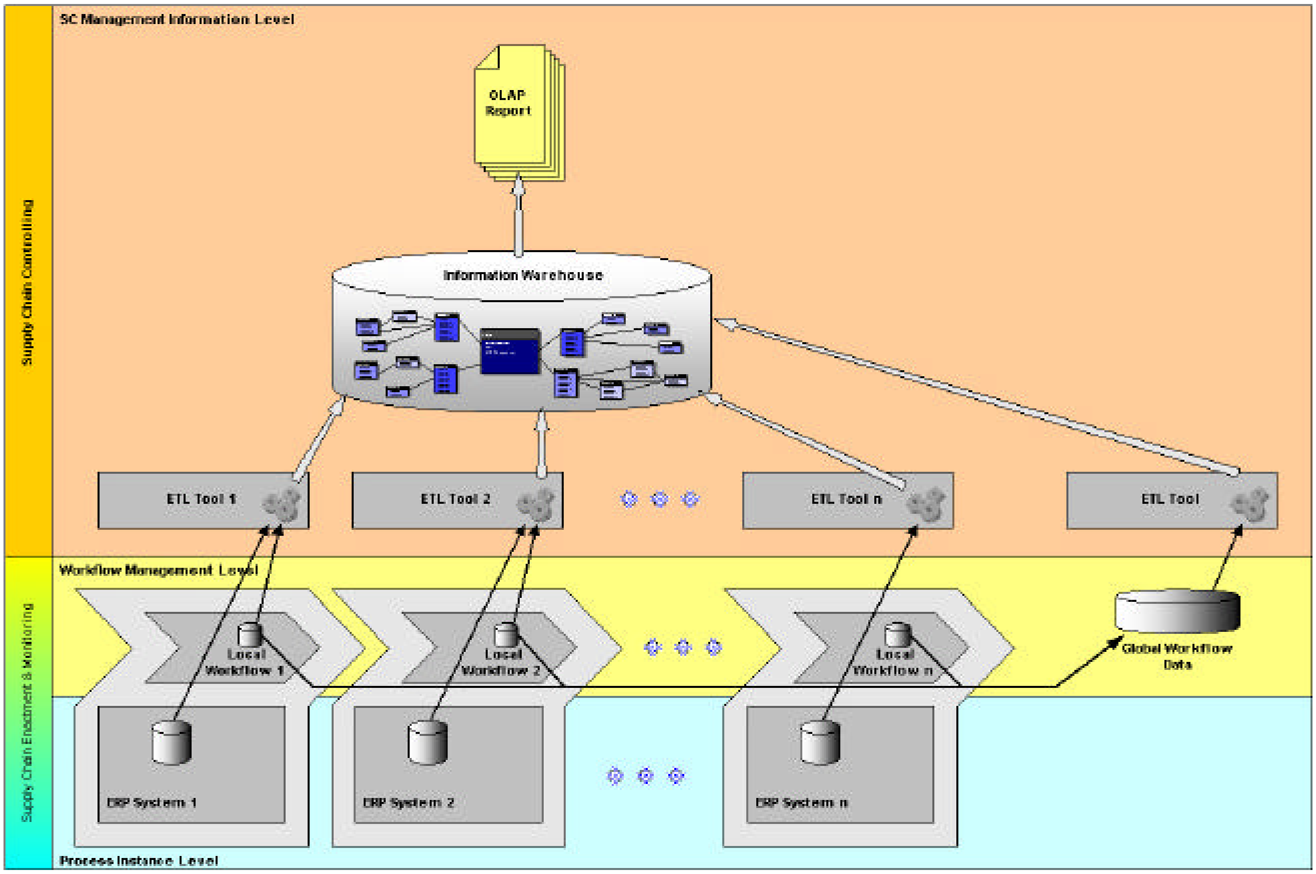

Figure 4: Architectural Framework for Supply Chain Controlling

6 Summary and Outlook

In this paper we have discussed the impact of information availability on supply chain operations. In order to benefit from lower inventory levels and shorter reorder times, a technical infrastructure is necessary to obtain the relevant information from the parties involved in the supply chain. A workflow-based controlling environment, serving operational level supply chain managers through the provision of global monitoring information, as well as tactical supply chain management through the integration of process data into an OLAP environment, is a feasible architecture for this purpose. The supply chain scorecard can serve as a tool for the management of supply chain operations at a tactical level, integrating financial and process information in a comprehensive manner.

Our future research will focus on the enhancement of the supply chain scorecard with additional perspectives and additional performance indicators. The integration of local and global controlling information will be another aspect of our future work.

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