Strategies and Tactics in Supply Chain Event Management

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Editors

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Foreword

This book aims at assisting global industry in its challenge of expansion within a world of ever increasing globalisation. The book wants to make the reader aware of the importance of transparent business processes and provides knowledge combining latest scientific findings and best practice in the high-tech industry. Major Companies provide comments and solutions drawing on their experience with regard to their special requirements with regard to Supply Chain Event Management (SCEM). Some model cases and examples give practical solutions in a tangible manner. Leading scientists in companies, managers, universities and research institutes explain and provide information about probable future requirements regarding SCEM development.

This book will assist not only the larger companies but also any smaller enterprises, such as Interturbine Logistik GmbH, in their efforts towards international speed delivery, service technology and competitiveness. It serves the common goal of networks transparency hereby offering significant cost reduction and providing ground for service performance enhancement, creating a base for total or partial business re-engineering.

For this achievement I like to express my admiration to the University of Aachen (RWTH) that has been able to combine science and the highly performing industry in order to gather all knowledge available at present in this compacted format (for more on this topic, see article by Raschid Ijioui on page 267 et seq.).

It is my vision that all modern companies that become aware of the importance of SCEM will remain competitive in the world market for a long time, until this process will become a regular practise of the bulk of industry world-wide one a day. I am sure that all the readers of this book will benefit greatly in their desire of adding value to their own organisation, even if only some smaller adaptations are implemented.

Burckhard Schneider
President and CEO
Interturbine Group of Companies

Preface

Companies and managers nowadays tend to have a ten year experience in supply chain management on average. The more attention is paid to supply chain management, the closer are the links between the partners. As a consequence of this, the success of the whole supply chain is directly linked to the individual ability of each partner to cope with unanticipated difficulties along the supply chain.

A collapse of only one element has disastrous effects to all partners. Therefore the novel concept of supply chain event management is more and more spotlighted. Leading companies report exceptional advantages in quality, speed and costs after introducing supply chain event management. However supply chain managers often spend up to 80% of their time in day to day problem solving.

Instead of this they should concentrate on strategies and ideas how to prevent interferences. Supply chain event management is the clue to the problem. This concept offers already approved solutions in trendsetting industries. The current challenge is to transfer these solutions into traditional industry environments. This book is intended as a book of recipes to achieve this vital task. It provides the unique insights of supply chain event management introduced by responsible practitioners from world leading companies in the global arena. Aims, methods and tools as well as resources and budgets in supply chain event management are discussed. Special attention is paid to organisational aspects and controlling approaches. In summary, the reader will gain a strong understanding for how to deal with problems along the supply chain and how to avoid them.

The editors' intention is that managers are not the sole readers of this book. Today the concept of supply chain event management has slowly moved from a domain of innovative commercial organizations to an area of academic interest. But even today the evolution in practical application outpaces academic reflection.

The editors wish to thank the authors of the individual articles. It is obvious that they had to shoulder a twofold burden in order to make this book possible. Furthermore we would like to thank Springer-Verlag (especially Martina Bihn and Gabriele Keidel), who has taken on this work in a constructive and open manner, as well as the CME-Team (especially Robert Prieler, Jürgen Hubert, Andreas Klein, Helmut Vor) for proofreading and great supports. We hope for widespread recognition of this work. The editors thank Lufthansa Technik AG for granting us the right to use one of their images as the cover illustration. The editors are always open for suggestions and information on further developments in the research field on SCEM and are looking forward to your comments.

Raschid Ijioui　　Heike Emmerich　　Michael Ceyp

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Introduction

The complexity of logistics networks increases constantly. The efforts of large companies and corporations to outsource and globalize lead to a permanent change in logistical structures. Linear supply chains give rise to complex value chains with network characteristics. Partners involved in the supply chain network – suppliers, customers, and logistics service providers – are integrated more deeply in the value-adding process. Along with vertical integration comes the partners' interdependence upon one another. Unforeseeable bottlenecks in logistics procedures – or even their complete failure – can even bring the whole supply chain to its knees in extreme cases. The consequences of such events are well known: Confirmed delivery promises to customers either cannot be kept or can only be kept at such a disproportionately high expense that the originally intended cost advantage to be attained from vertical integration quickly becomes the exact reverse. To minimize the risks of availability and failure along with the resulting risk of customer dissatisfaction, it is necessary for logistics processes to be guided efficiently. Or to put it another way: Companies that globalize their business processes in whole or in part and simultaneously outsource them to external partners on the basis of out-tasking models need not only to plan all steps diligently but also to monitor their scheduled implementation continuously. To manage this, new methods and tools for Supply Chain Event Management (SCEM) can help to monitor the progress of business processes and report any deviations from plans in a timely fashion.

"Event" Minimization with Supply Chain Planning

The more exact the plan is, the lower the risk is of potential deviations from the plan. Following this trivial sounding logic, supply chain planning that is as exact and realistic as possible undeniably contributes to reducing the risks of availability and failure. Viewed in these terms, the avoidance or, at least, minimization of "events" – the appearance of unplanned occurrences – can be thought of as the main task of solid planning. The essential components of supply chain planning thus cover these items, among others:

- Coordinated demand forecasts
- Coordinated allocation of inventory and capacities
- Coordinated business process design
- Coordinated information systems

Companies have increased their investments in planning methods and systems in recent years. These investments are intended to close the gaps that inevitably exist when using conventional ERP systems for planning. The overwhelming majority of ERP solutions available on the market work on the basis of a successive planning philosophy. This means that all planning steps are taken one after another. There is almost no feedback to earlier planning steps, so that changes arising later on are no longer taken into consideration in the plans. Modern supply chain planning tools, in contrast, are based on a simultaneous planning philosophy. These aim to give the planner a total overview, as it were, of the value-adding process and all the relevant influencing factors. If a planning parameter changes, this change can be taken into account in the plans near the time it arises.

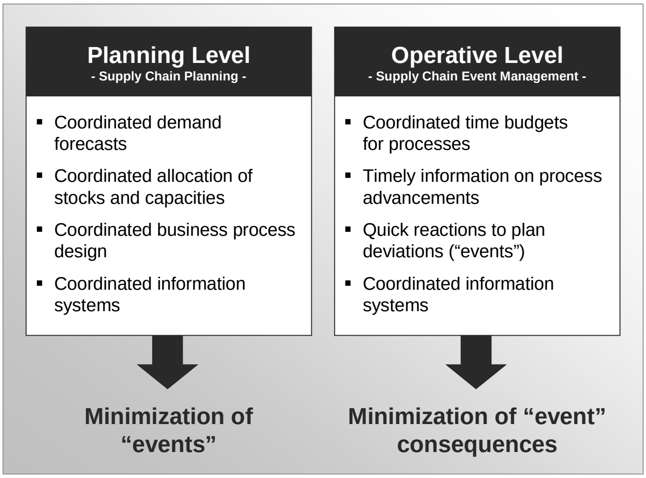

Fig. 1. Objectives of supply chain planning and its operative application

What seems quite reasonable in theory is nonetheless rather difficult to apply to business in practice. Because of the growing complexity of logistical structures, the number of planning parameters has expanded so dramatically that changes to individual influencing factors are not directly recognizable within the general web of planning parameters. Although planning quality has improved markedly thanks to refined planning processes and tools, considerable deviations from the plan at times arise when business processes are carried out. In business practice it still remains impossible today to take all existing influencing factors into account when making plans. Before this could happen, the planning company would have to have access to all business-critical information on all the earlier and later steps of the supply chain. Since not all participants consistently desire to achieve this type of supply chain transparency, one generally restricts the focus to a selection of the most important planning parameters. And this places limits on supply chain planning in practice. The lofty goal of avoiding “events” can therefore not be realized. Thus, at the operative level in business practice, solid planning can only help to minimize “events” (see Fig. 1).

Damage Control with Business Process Monitoring

If the occurrence of unplanned events can thus be minimized at the operative level, but not entirely avoided, the aim should be to discover looming deviations from the plan early enough to counteract their potential negative effects by applying appropriate avoidance measures. For example, if a production machine fails unexpectedly, a supplier will deliver the required materials at the wrong quantity; or if a shipment is delayed due to poor weather conditions, this may lead to an unpredictable deviation from the original plan. This is where the SCEM concept takes hold. SCEM tools continuously monitor the logistics processes across the network on the basis of predefined “events”. If a specific instance occurs too late, unexpectedly, or not at all, the SCEM tool generates a report giving notice of the deviation from the original plan. Ideally, SCEM tools help to identify plan deviations within the supply chain in real time. A company can then respond immediately to sudden bottlenecks or failures with the appropriate adjustment measures. The result-oriented control of the supply chain allows process advancement to be monitored on the basis of process milestones without monitoring the resources committed in every case. The process milestone can be derived from the plan. The plan determines the exact time or the timeframe in which a specific event is to occur according to the plan. Four types of events can be distinguished in principle:

- A regular event occurs at a time or within a window of time when it would be expected to occur.
- A delayed event only occurs after a time or timeframe when it would be expected to occur.
- An unreported event should have occurred at a time or within a timeframe but didn't – not even as a delayed event.

- An unexpected event occurs at a time or within a timeframe even though it was not expected.

If an event occurs, this means that a step of the process has successfully been completed. The next step of the process is then initiated as a rule. If, for instance, a spare part leaves the warehouse, the part is checked out of the stocks according to schedule in the ERP system, which views this as a regular event. The next step of the process is the transfer of the spare part to the shipping company. The lading itself is the corresponding event. If this lading of the replacement part occurs after the scheduled point of time in the plan, the event is recorded as late or delayed. The appropriate employee is then informed of this status via e-mail. The employee can then respond in a timely fashion by introducing steps to correct the problem and, if needed, call for an express delivery service.

Cost Killers in Spare Part Supplies

Considerable potential for the use of SCEM is found in industrial fields where very realistic supply chain planning is made exceptionally difficult or only possible at great expense due to the large diversity of possible influencing factors (see Fig. 2). One of these fields is the organization of logistics in after-sales service that is meant to ensure spare part supplies and that bears responsibility for all relevant logistical procedures. Whether this entails delivering spare parts in the trunk of the service technician's car or directly delivering them to the place of installation – each spare part has to be guided through the logistics network precisely and in a time-critical manner. In the case of a machine breakdown, for instance, the disabled machine can only be returned to service and production resumed if the required spare part arrives at the point of installation at the same time as the service technician.

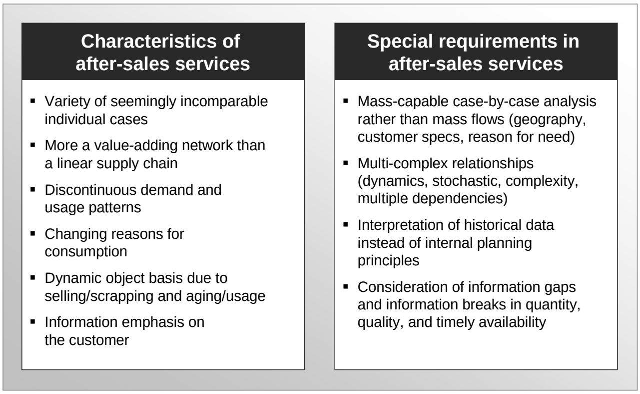

Fig. 2. Business drivers for the use of SCEM in after-sales service

SCEM systems offer major potential for optimizations in the areas of handling returns and repairs within a reverse logistics network. Components and assemblies can often be repaired quickly and at reasonable cost in specialized repair workshops. This results in a quick, transparent return of the repaired components – helping to avoid cost-intensive new purchases.

It also makes it possible both to set up databases for the support of warrantee processing and to track removed defective components. Safety-critical businesses use SCEM tools to register individual parts of a machine on the basis of the serial number so as to model their defect rates and to predict the lifecycle of these parts in operation. Project examples show that the return process can be reduced to just a few days using SCEM. This reduces the capital tied up in defective parts by as much as 70 percent. Taken together with the appropriate stock planning solutions, SCEM tools form a solid foundation for optimized management of a holistic reverse logistics network in after-sales services.

Sustainable Optimization of Logistics Performance Using KPIs

When using SCEM to manage business processes, the few availability-critical events have to be filtered out of the mass of events that occur due to the highly complex nature of logistical networks. Not every status report generated is relevant for initiating later processes. In the end, SCEM tools are meant to offer an efficient aid for decision-making and should only inform users about deviations from the plan that jeopardize the smooth operation of the business process chain. The introduction of an SCEM tool requires an exact analysis of which logistical procedures are critical and thus need to be continuously monitored.

Aside from the reactive control of the supply chain on the basis of deviations from the plan that actually arise, an assessment of the performance of logistics provides an opportunity to discover looming bottlenecks beforehand. This makes it possible to improve the performance capacity of the entire supply chain permanently. Main logistics variables – Key Performance Indicators (KPIs) – allow the performance capacity of business processes to be measured. One significant KPI in the transport field would be the number of delayed part deliveries as a ratio of the total number of part deliveries as related to a specific freight forwarder. If this indicator exceeds a predefined threshold value, the employee in charge is automatically informed. This helps to gradually discover the weaknesses of a logistics network and then introduce response measures that not only minimize the knock-on effects of “events”, but also eliminate their causes over the medium term.

Altogether, this gives logistics departments the opportunity to perform an integrated measurement of their performance capabilities from the supplier all the way to the point of transfer to the customer. The data and information made available by an SCEM tool can be used efficiently in the manner of strategic performance controlling. The reasons for deviation from 97-percent availability in receiving orders and from a delivery rate of 85 percent as measured by the customer are made transparent and can then be eliminated.

Software for Supply Chain Event Management

The market for SCEM software solutions is still young, which explains why integrated SCEM solutions are still a rare find. Major ERP system providers have an advantage because their products offer close linkage to transaction systems, yet methodologically, they are pure adaptors of standard procedures. Specialists, in contrast, often do not cover the whole functional area required for SCEM, yet they act as serious innovators who increasingly offer standard interfaces for exchanging data with commonly available transaction systems.

The special SCEM tools most commonly found on the European market include the products from the US software makers Descartes and Viewlocity and solutions from the German providers Axit and Star-Trac. Products from the specialists generally access data from existing transaction systems – whether standard ERP systems like SAP or legacy systems – via interfaces and use the data in additional processing according to the business process logic and rules defined in advance. This makes it possible to ensure comprehensive process transparency along the supply chain. The products evaluate the operative data on the basis of predefined events. Integrated alarm functions point out deviations from planning that are critical to availability.

The makers of extensive software suites for supply chain management (SCM) have also integrated SCEM tools into the products they offer. Thus, the firm i2 Technologies offers an SCEM solution it calls “Supply Chain Visibility” that contains functions for the event-oriented control of the supply chain. JDA Software, in its “Logistics Event Management & Visibility” component, also provides a module in its program that enables companies to monitor business processes in logistics networks. While the i2 Technologies products primarily find use in technology-oriented industries, JDA Software can be thought of as having its main emphasis on retail and in consumer product industries.

SAP ships an SCEM component in the framework of its product series “Supply Chain Management”. Especially for companies already using SAP solutions, this product has the advantage of easy integration into existing SAP systems. Aside from SAP, other major ERP software makers offer products for the event-oriented control of logistics processes. Yet these are generally limited to managing transport processes. In the framework of its “Applications” product series and as part of the product packages from Peoplesoft and J.D. Edwards, Oracle offers modules that allow companies to guide physical merchandise flows from suppliers, to customers, and within their own companies. The modules include standard interfaces to major express shippers including UPS and FedEx.

Because reference projects have as yet been rare, interested companies should pay particular attention to product maturity when choosing an SCEM software solution. This can best be determined by noticing successfully completed reference projects. Small, service-oriented providers manage to do quite well on the market due to the amount of integration required. In the fields of legacy systems and complex system environments above all, small and medium-size specialists will continue to succeed over the mid to long range.

Potential Criteria for Selecting Software

When selecting an SCEM software tool, it is a good idea to use a standardized list of criteria. This list should cover abstract criteria in equal measure, including the software provider's market position as well as project-specific criteria such as dedicated functions that are subject to project requirements. The following list of criteria offers some initial considerations and can be liberally extended and adapted as needed.

It is worthwhile to assess the software provider in terms of "softer" criteria such as market position and reference installations before performing extensive analysis on product functions and system architecture. It is most often quickly obvious after the former assessment whether or not a provider can understand and meet the requirements of the respective project – independent of the bits and bytes involved. The following criteria form a basis for performing such a provider evaluation:

- **Stability and market position of the provider**: Is the provider known for its satisfied customer base, a solid financial foundation, and innovative capabilities necessary to meet our future requirements?
- **Relevant references**: Is the software successfully in use at other companies that have specifications comparable to those of our own organization in terms of function and technology?
- **Process know-how:** Does the provider have suitable partners such as specialized logistics consultants who possess definitive process and organizational know-how of their own of use to our software selection and implementation project?
- **International scale:** Are the provider, its software, and its partners capable of supporting the international orientation of our organization in the framework of introducing and operating the software over the long term?

Once the software provider has taken this first hurdle, the functional and technical features of the software need to be evaluated in greater detail:

- **Functional depth**: Does the software offer a real, comprehensive event management function that goes beyond traditional tracking and enables a seamless depiction as well as active monitoring and management of enterprise-wide business processes?
- **Future-ready basic technology**: Does the software operate on the basis of a technology already widely in use at our organization such as Java or Microsoft.NET, and does this technology also match our long-term enterprise-wide IT strategy?
- **Modular system architecture**: Does the software have an open, web-based system architecture that is scalable both in terms of function and increasing transaction volume, and can it grow along with our requirements accordingly?

- **Interfaces to standard systems**: Does the software provide standard interfaces to ERP systems such as SAP and other commonly used enterprise applications?
- **Interfaces to proprietary systems**: Does the software in its standard version also support the connection to legacy and third-party systems via XML-based interface converters?
- **Functional integration**: Does the software permit the functional connection to logistical systems, especially to planning systems, so that the logical connection of planning and control is realized on the system side?
- **Integration of logistics service providers**: Does the software in its standard version integrate the processing systems of major logistics service providers so that our organization can perform consolidated monitoring of shipments with the aid of the software?
- **Workflow modeling**: Does the software support standard methods for business process modeling, especially UML (Unified Modeling Language), or is there an option for integrating ARIS?
- **Output management**: Does the software provide the option of making subfunctions available over different channels like mobile end devices, e-mail, or integration in ERP systems?
- **Management of access permission**: Does the system allow the administration of different users with different usage permissions – above all from outside our organization – via procedures such as RBAC (Role-Based Access Control)?
- **Alarm functions and processing logic**: Does the software make rules-based alarm functions available, for instance, to allow users at our organization to use hierarchically organized alerts for processing?
- **Reporting functions**: Does the software offer functions for ad-hoc reporting that can be flexibly adapted to the needs of users at our organization in terms of content and format?

Aside from the functional and technical capabilities of the software, its implementation and operating costs should be evaluated on the basis of the implementation strategy recommended by the provider and in terms of the business concept. Alternative business models are becoming more important in this context, including “software on demand”, where companies pay for using the software as a rule via transaction-based billing models. The consideration here is as to whether the number of transactions expected justifies an in-house implementation that requires high initial investments. The following criteria are helpful for evaluating implementation and operating costs:

- **Training concept and expense**: Does the software provider offer a convincing and efficient training concept that can help to ensure acceptance of the software among all the employees and partners involved at our organization in a quick fashion and at the international level?

- **Support capacity**: Can the software provider also provide a competent support team that will support the languages spoken at our organization and that is available around the clock?
- **Licensing and integration costs**: Can the costs for the adaptation, introduction, and operation of the software be clearly quantified and evaluated in terms of a cost-benefit ratio?
- **Alternative business models**: Does the software have a service-capable system architecture (SOA) so that the provider can operate the software even via hosting or on-demand models and provide invoicing for usage on the basis of transactions?

Supply Chain Event Management in the Pharmaceutical Industry – Status and Outlook

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Introduction

Supply chain event management combines the real-time modelling of relevant business processes with early warning systems. This means that SCEM attempts to help the sequences of internal and external processes run even smoother throughout the supply chain. Before focusing on establishing individual SCEM tools for use in the pharmaceutical supply chain, we should take a look at the supply chain as a whole and the potential for optimising it. The supply chains in the pharmaceutical industry are often highly integrated and are characterised by long processing times.

However, concepts do exist for visibly speeding up these processing times (Küppers 2006, Ewers et al. 2002), which also create the new requirements for "tracking" and "tracing". Pharmaceutical production has been plagued for a very long time by a classical production process. This gives rise to a number of weaknesses:

- the production process lasted up to 1,000 days in certain cases, whereby the length of time required for the production process in chemical production depended on the number of synthesis steps and varied considerably from around six months to two years,

- the expansion of production capacities was hardly ever possible in less than four to five years (for example doubling the entire production capacity for a product),
- due to lengthy processing times and the difficulties involved in capacity adaptation, a capacity buffer of at least **half of the annual requirements (!) (**included intermediate stocks) was introduced between chemical production and pharmaceutical formulation,
- the entire process of chemical and pharmaceutical production is historically enormously complex, whereby the end product of the chemical/microbiological synthesis, for example, was also active ingredient for a drug and the starting material for further chemical/microbiological synthesis,
- distribution occurred and often still occurs via a multi-stage retail cascade and was often combined with interim storages that were not coordinated with each other.

The cost pressure that has emerged because of demographic change on the one hand and because of progressing globalisation on the other has caused considerable changes in the area of the production of active ingredients. Pharmaceutical production and distribution are still undergoing a process of change. Pharmaceutical production, packaging and distribution have become locally different concepts that will have to be realised in a global overall strategy. However, when taken as a whole, it is obvious that the cost pressure in the pharmaceutical industry, just as in many other industrial sectors, is causing attention to be increasingly focused on the management of the supply chain. In order to monitor and permanently optimise the process, supply chain event management tools are now being used (Küppers a. Ewers 2007). The automobile industry and to a certain extent, the food industry, have long been used as models for this transformation process.

Peculiarities of the Pharmaceutical Industry

The pharmaceutical industry will continue to be different in certain instances from other industries. Some important points for the context of this paper will be outlined next. In terms of bottlenecks, for example in the food industry, the consumer can usually turn to similar products. When there are bottlenecks in the automobile industry, for example vendor parts, then a replacement car can be made available. When it comes to patent-protected drugs, these alternatives simply do not exist. Even in cases where it is possible to substitute a product in principal, it is often regarded as risky by consumers/patients and doing so therefore leads to a lasting breakdown in terms of consumer satisfaction. Some of the influences to which the pharmaceutical market is exposed cannot be foreseen and arise very quickly. Reoccurring flu epidemics are a good example. The high number of tourists means that such epidemics spread in a chaotic pattern. Here, drugs must also be available at short notice. Long-term stable availability of a set amount is also essential for other illnesses and in particular for illnesses that can be life-threatening, as is the case here. Regulatory requirements have led to the pharmaceutical industry becoming much more inflexible than other markets. If a particular food product was in short supply (e.g. bananas), then the price would increase, which would lead to a decrease in demand from some consumers. In the pharmaceutical industry, it is not just the price that is absent as a regulatory mechanism, but also delivery – e.g. in most countries in the world, the regulatory system rules out the delivery of half a packet of a certain drug when it is in short supply. The result of this is that the pharmaceutical industry's ability to deliver goods is extremely high and will continue to lie at almost 100 % in the future. As a rule in Europe, a drug must be obtainable for every illness within 24 hours. This also holds for example if an illness breaks out locally on a larger scale. These results automatically in higher safety requirements compared to other industries.

The factors that cause sudden fluctuations in market demand are manifold and since the consumers (patients) very rarely change their behaviour to suit the prices, this frequently leads to fluctuations of much greater amplitude than in other industries. The following factors give typical examples:

- the expiry of a patent if accompanied by the availability of a generic product,
- the approval of a new more innovative or more tolerable product,
- a change in consumer behaviour can be caused by a single newspaper article, e.g. on particularly rare or ominous side effects,
- the prohibition of a drug by the authorities can lead to a sudden dramatic demand for another product,
- political changes, e.g. to the additional payment policy, can have a direct and dramatic influence on consumer behaviour.

Despite these regularly occurring influences on the requisition for supplies, there are also a number of examples of established drugs, particularly those for chronic illnesses, which show a uniformly increasing or decreasing and even an almost constant demand.

In order to cover all of these criteria, the supply chain needs a higher degree of flexibility. This is not always accompanied by larger buffer stocks or longer processing times, as was the case in the past. Vis-à-vis the still partially established system, such an objective amounts to a paradigm shift.

Overview of the Pharmaceutical Supply Chain

An analysis of chemical production reveals that production has led to an optimisation that is almost exclusively focused on cuts in the production amount per volume dimension. The resulting campaign characteristics or mode of operation consisting of a number of stages in (extra)-large production facilities, has also led to considerably longer processing times.

Moreover, the agitator vessels used are often technically oversized and therefore very costly, because they have to be suitable for use with as many products as possible. The problem of oversized facilities also faces pharmaceutical production. However, pharmaceutical production must be viewed more discriminately than chemical production because here product differentiation occurs within the pharmaceutical supply chain. In the production world that still prevails to some extent today, a stronger focus is placed on the utilisation of facilities than on an overall optimisation of costs. In the future, it will be more important to get the processes "flowing". In practice, this means very short processing times – e.g. using dedicated facilities in chemical production; using high synchronisation and quick order changes in pharmaceutical production or in certain cases through dedication as well.

The reasons behind the increasing demand for flexibility in the pharmaceutical production supply chain are varied. First and foremost, globalisation has left its marks: the variety of articles as well as the number of packages that have to be specifically produced for each country at centralised sites is increasing, while batch sizes per order are decreasing. In addition for example in generics the profit margins decrease caused by competition. Furthermore, pharmaceutical research is leading to a growing palette of products for a more individual treatment of more and more illnesses. "*The decoding of the human genome is making it possible to identify potential new targets for drugs on the basis of genes. Today, we assume there are thousands of targets. This is an enormous increase compared to the approx. 400 known targets. With the further development of genomics into proteogenomics, we will find a hardly conceivable number of completely new targets (…) in the future*" (translation of the original quote in Pharma Innovativ, BPI, 2004). With the further development of galenics and the ensuing reduction in how often a drug must be taken, compliance improves – a primary goal for the health sector as a whole. This inevitably means that a reduced amount of drugs are required, ergo smaller order sizes.

The hitherto largely homogeneous pharmaceutical market is being split into ever more heterogeneous smaller sub-markets. The trend towards individual packaging is seeing a high proportion of standardised large batches being replaced with small, consumer-oriented or country-specific packages that vary in form, colour, dosage, blister and pack size, print, cardboard, foil, information leaflet, etc. Packages have new functions, for example

- communication of the brand
- protection against counterfeiting
- compliance support
- senior friendly
- child resistant

and in the future, they will also be handled very individually worldwide. All of these trends indicate that we will eventually have a much greater proportion of small products.

Independent of the size of the order in chemical or pharmaceutical production, a linear process will emerge for future production planning. Metaphorically speaking, the transportation of products will undergo a transformation process and be carried out using an escalator instead of an elevator. The escalator will continuously deliver material to a destination, whereas the elevator only ever delivered large individual batches. The image of the escalator is one that is extremely helpful for the discussion on the supply chain and we will continue to refer back to it.

In general, the "escalators" for chemistry and pharmaceutics are conceived differently but they are buffered at the interface. In chemistry, the same product is produced in many cases on a quasi-continuous basis. In contrast to the chemical industry, on each of the escalator steps in pharmaceutics, there is a different type of package (either a different product or only different packaging). However, there are also examples for biotechnological drugs, whereby only one "escalator" is used for the entire process.

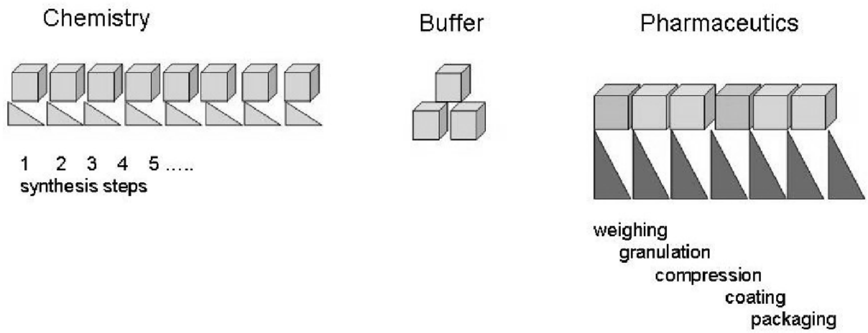

Fig. 1. Overview of the synchronised chemical production supply chain in dedicated facilities and the flexible multi-purpose concept (i.e. a facility is used for a number of different products) in pharmaceutical production

Modularisation for the Maintenance of Long-Term Flexibility

An intense synchronisation of the individual process stages in the pharmaceutical supply chain could be viewed as a loss of flexibility. This can be countered with a rapid expansion of capacities. Interestingly, the solution in the form of modularisation and a high standardisation of facilities originated in the closely related food industry, where it was developed by the company Alpha Laval Tetra Pak in the 1980s (Stjernberg 2002). When Alpha Laval merged with Tetra Pak, management and technology came up with a modular approach which considers a facility for drink filling as a combination of X components or a combination of root (X) modules (formula of operation at Alpha Laval Tetra Pak). One advantage of modularisation is that that a new facility can be designed and built much faster. Another is that it makes it possible to expand capacities as required by "numbering up". Both effects lead to a decrease in total costs. With regard to the erection of buildings, this concept has been optimised over the last few years by two other Scandinavian companies. On the one hand, Novo Nordisk Engineering (NNE) (Broch-Nielsen 2003, www.nne.com) heavily standardised and then parallelised the design and construction process. This allows NNE to begin building new production sites without needing to know what the interior of the facility should look like, and to speed up the construction process, modules can be bought all over Europe today.

In Pharmadule's concept, the production facilities are assembled in a former ship hangar using prefabricated standard steel frames (Savage 2002, www.pharmadule.com). Since this "building site" is protected from the weather, short and more importantly "guaranteed" times for the assembly of the production modules become possible. The production module is then trucked or shipped to the production location, where it is then put into operation. The interesting point here is that the construction of a production facility can be replicated in record time, and if the technologies already mentioned are used, then the pharmaceutical production sites can be expanded very quickly. Pharmadule has not just manufactured pharmaceutical facilities but also facilities for the production of active ingredients.

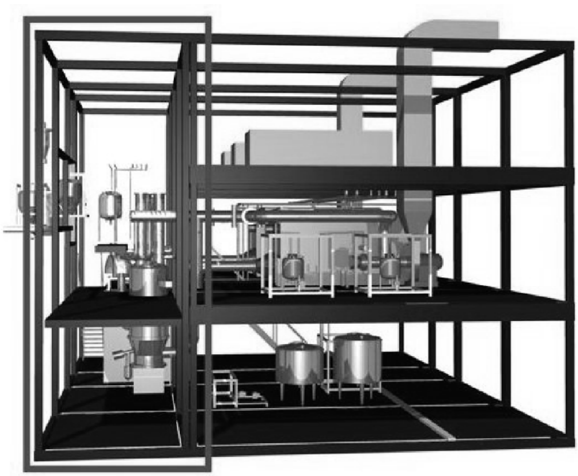

Fig. 2. Modular construction of a pharmaceutical facility. The frames indicate the steel modules used to assemble the facility (reproduced with kind permission of Pharmadule, Sweden).

The next stage in modularisation will mean applying this system to the production facility itself. This can be done, for example, using complete ventilation modules as is the case for the facility shown in figure 2. Similar options have also been developed for production facilities in the chemical industry. Merck in Darmstadt (Lüneburg 2005) are an example of a company who have constructed facilities from a kit of highly standardised modules, as shown schematically in Figure 3. The cost and time invested in engineering could therefore be significantly reduced.

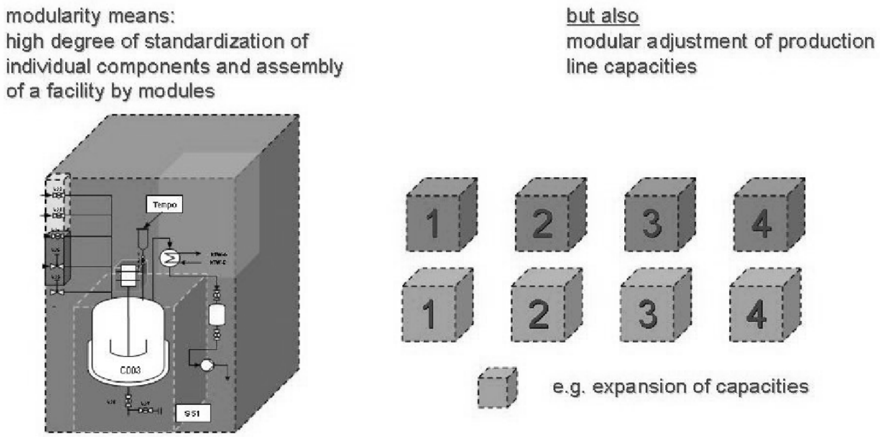

Fig. 3. Dimensions of modularity in the area of production facilities in the pharmaceutical supply chain.

If you bring all of these aspects together, it will be possible to switch on or shut down individual units in future, depending on the situation requirements, and in the case of the latter, to re-use them in another place. This means that technologically nothing is standing in the way of the management of the supply chain in the pharmaceutical industry in analogy to other industries, such as the automobile industry. We can therefore assume that if a company is built in this way, then in less than a few years, the main issues associated with pharmaceutical production that have swung from *"when will we have so much of a product?"* and *"when will the chemical production warehouses be empty again?* to "*when will an application be available again?* will all have been solved.

The Supply Chain for the Production of Active Ingredients

The supply chain can be sub-divided into the following segments: active ingredients, formulation/finishing and packaging. Active ingredient production should be viewed as production that is operated continuously, quasi-continuously, or in exceptional cases in a "multi-purpose" manner with extremely fast changeovers in analogy to an engine factory in the automobile industry.

When dedicated facilities are used for just one product, a large number of small agitators instead of over-sized facilities are used, and these are arranged analogous to a conveyor belt used for production in the automobile industry. A change in the technologies used until now is therefore not necessary. An important advantage of this approach is that the change from multi-purpose to continuous or quasi-continuous is no regulatory change. With this linear arrangement, many logistical processes involved in interim storage immediately become redundant. This simplifies the entire production process and ultimately leads to an easy decrease in processing times from > six months to less than two weeks (Ewers and Küppers 2002, Behr et. al. 2003). Production activities are equipped with a buffer of starting materials and interim buffers of a small number of "key intermediates". In a best-case scenario, each of the production stages will be represented by at least two facilities, see Figure 4.

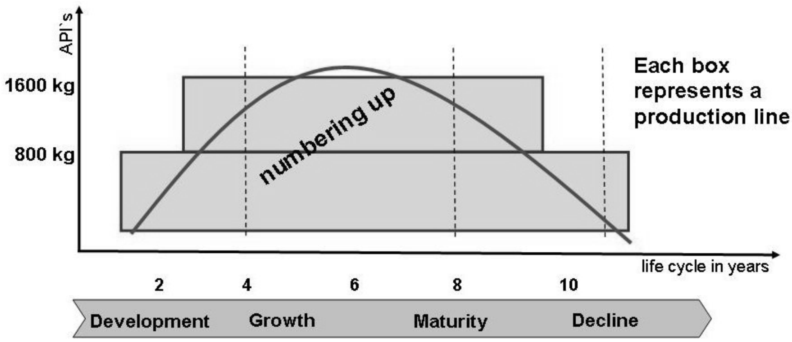

Fig. 4. Facilities and capacity utilisation in chemical production throughout the life cycle of a product

In the case of products with good market acceptance, the number of simultaneously run facilities can exceed this number many times over. Since up until now, this approach has seen a small number of large facilities being replaced by a large number of small facilities, a cost discussion would perhaps be beneficial at this point. However, this has already been conducted in detail in another paper (Ewers et. al 2002). Ultimately a general survey of the costs involved in the supply chain shows that they are significantly lower than costs up until now associated with the classical approach.

The image of the supply chain in the "new" chemical production model – again, we refer back to the image of the escalator – appears to be a multi-stage process in which the individual stages are (quasi-)continuous. The individual processes do not necessarily have to be run by the same owner. They can be run in the form of collaborations. Individual parts are already being operated today on a "collaborative" basis (Ewers a. Küppers 2004). Depending on size and strategic significance, chemical production right up to the "final intermediate" (the last "key intermediate" in chemical production) may be outsourced, or in the case of an active ingredient that is not patented, then set (weekly or monthly) consignments are simply agreed upon with external suppliers. In this case, the active ingredient itself is the first warehousing stage with a buffer of a weeks' or months' supply (depending on the arrangement).

In preference to modularisation, outsourcing in stages would be simpler. This would leave manufacturers free to look at market proximity as well as costs when choosing a location, or to fabricate certain steps themselves in order to protect technologies and patents. Ultimately, however, many of these production sites will be located in Asia because this is where the largest market for the future is and the production costs are low here.

SCEM in Chemical Production

In the procedure described, tracking and tracing become much simpler as a result of a clearer distribution of products to facilities on the one hand and short processing times on the other. The constancy of production leads to less deviation in production and when this does occur, it causes little depreciation because the batch sizes are smaller. Furthermore, establishing product-specific quality control systems becomes much easier. The latter, together with the quality analyses conducted in the production cycle, lead to simple early warning systems.

The principle behind the use of SCEM can be described using the example of a field charge in chemistry, whereby this example is also relevant for pharmaceutics. It can be expected, for example, that the agitator breaks down during one of the last stages before we come to the active ingredient stage. This means that this stage cannot be completed in one step. When the data acquisition of this batch is compared with standard estimates, a difference in quality can be detected even before a more in-depth risk analysis is conducted. This approach is incorporated and the gaps in production volume can be accepted (due to the small amounts involved). The availability of the active ingredient is not taken into account because of the existing reserve stock. Postproduction and the replenishment of the buffer take place later. The reserve stock is only moderately affected and additional added value through the further processing of a material lacking in quality is avoided. After all options have been examined, the intermediate product is reprocessed if required and then reused.

The Pharmaceutical Production Supply Chain

Production differentiation in the pharmaceutical supply chain only begins after the active ingredient has been fabricated, and in many cases, only after package design. From a production point of view, the latter is the simplest variant. At least in the case of pharmaceutical companies involved in research who have to cover high R&D costs for new active ingredients, new products will be introduced in at least 100 countries.

Thus the need for control arises very easily from the accumulation of individual fluctuations in the high number of sale forecasts, whereby errors can develop into significant miscalculations by the active ingredient stage. Fluctuations on the market are, as mentioned earlier, very heavily dependent on the type of product. The unreliability associated with forecasts is therefore also very heavily dependent on the type of product. Products for chronic illnesses, for example, tend to experience much lower fluctuations than products for e.g. flu medication.

The complexity that arises as a result of the different uses for active ingredients in different combinations in the preparations must also be investigated.

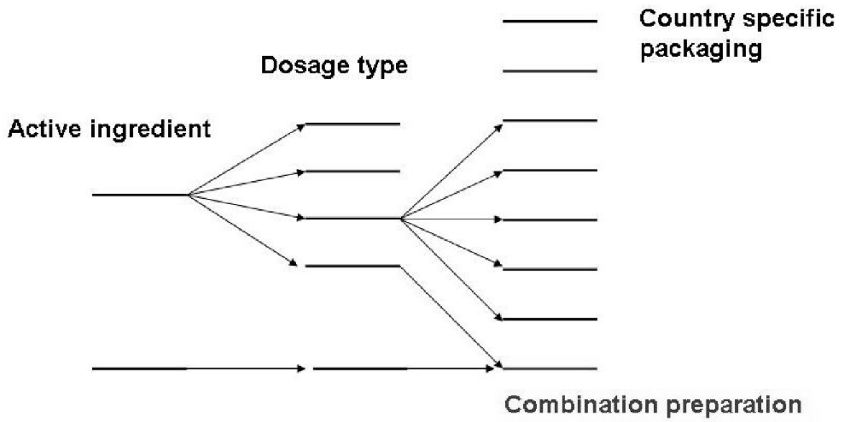

Fig. 5. Complexity in the pharmaceutical supply chain is significantly increased because of different forms of dosage, variations from country to country and combination preparations

Figure 5 shows a very simplified example. It is intended to illustrate that an active ingredient is often used in different quantities. This leads to a situation where not just one preparation but rather a number of preparations are available, which are then divided up according to country-specific packaging (language, design). In practice, the situation becomes even more unclear because a large number of preparations contain more than one active ingredient (and often in different quantities). The active ingredients then come from different synthesis lines (usually different production facilities).

Modelling the entire process that a product goes through reveals a complex network with a large number of different weighting factors. Yet here too, decomplexing and accelerating the processing times are possible. During the fabrication of tablets, which involves the process of granulation, compression, coating and packaging, shorter processing times in combination with synchronous production and fast changeovers can be achieved. In analogy to our image of the escalator (Fig. 1), it is not necessarily one single product but "packages" of a similar size that are fabricated in facilities with a similar work cycle that coordinate their activities. Use is generally not made of interim storage and the production volume is regulated by the "pull" principle of sales on the market.

While one (or two) supplier(s) for the active ingredient is needed and only a small amount of bulk additives have to be used during formulation, the packaging process involves multitude of partners. The pharmaceutical product (e.g. tablets) is turned into a product by the pharmaceutical manufacturer using the packaging (e.g. bottle or blister pack) delivered by the first supplier, a leaflet from another supplier, a label or aluminium foil manufactured by a third vendor and a cardboard box from a fourth manufacturer… . The aim is that all of the components be delivered to the right place at the right time in the right quantities with the lowest possible production costs, minimum transaction costs and if possible, without any warehousing. However, this is hampered by the fact that parts of the packaging, for example the very important cardboard box, are being increasingly used as marketing devices and as proof of the product's authenticity, which means that more time and effort has to be devoted to its conception and production.

First of all, we will take a look at the production equipment before going on to look at process control. The required combination of facilities for a coordinated supply chain process during finishing is only rarely achieved today because synchronising production equipment with the production cycle (duration of the longest process step) is usually inadequately performed. The speed of the packaging machines, in particular, is much higher than it should be for economic production because of individualised market demands. The reasons for this are quite obvious.

For decades, the growth of the pharmaceutical industry was very strongly influenced by the volume to be produced (push strategy). The production structures were therefore accordingly configured: high speed machines dominate the scene today; the number of blister packs per minutes is still an investment criterion for machines. However, other qualities have to be taken into account today, namely intelligence and flexibility.

Practical experience has shown that although the awareness of this issue is growing in the industry, actually putting it into practice often proves much more difficult. The reason for this is the attempt to incorporate small batches into the existing production structure. Often this is done using existing machines, which are unsuitable – with the result: the smaller the order, the higher the costs. High performance and flexibility are followed by other principles and require very different forms of organisation and individual infrastructures.

There is no question that small batches remain unpopular today because they are unprofitable from an economic point of view. Nevertheless, the degree to which the majority of pharmaceutical companies are suffering is not yet great enough.

Some machine builders have already begun to rethink their approach. They offer a wide range of packaging equipment including smaller and more flexible packaging machines whose advantage lies in the optimisation of changeovers for small batches or avoiding downtimes completely (Bauernfeind a. Konold 2005).

If demand increases at a moderate rate, the distribution can be adjusted quickly from the annual volume and instead of the usual cycle, products can frequently be produced one after the other, as shown in Figure 6.

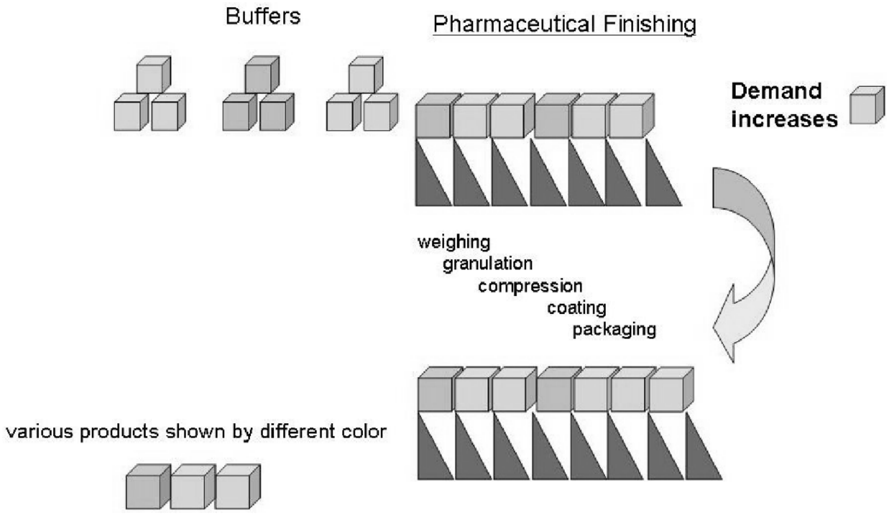

Fig. 6. If demand increases, it is possible to adjust the finishing output to meet the demand using very short planning cycles

Any fluctuations in demand that occur can be controlled by introducing additional shifts. All activities are concentrated on a short processing time, which directly affects the volume of reserve stock. If capacities prove insufficient on a long-term basis, additional escalators are installed.

In the following sections, an overview will be given of another simplification of the production process. "Decomplexation" occurs through a stringent analysis of the supply chains of individual products and through technological and organisational changes. The basis for this is provided by modularisation and synchronisation.

If product differentiation is only necessary in the form of country-specific packaging, then the first step towards simplification can be taken by creating a buffer at the bulk ware stage (unpacked products), see Figure 7. In order to realise this, a synchronised production line is required at all times for a preparation's packaging, which varies from country to country.

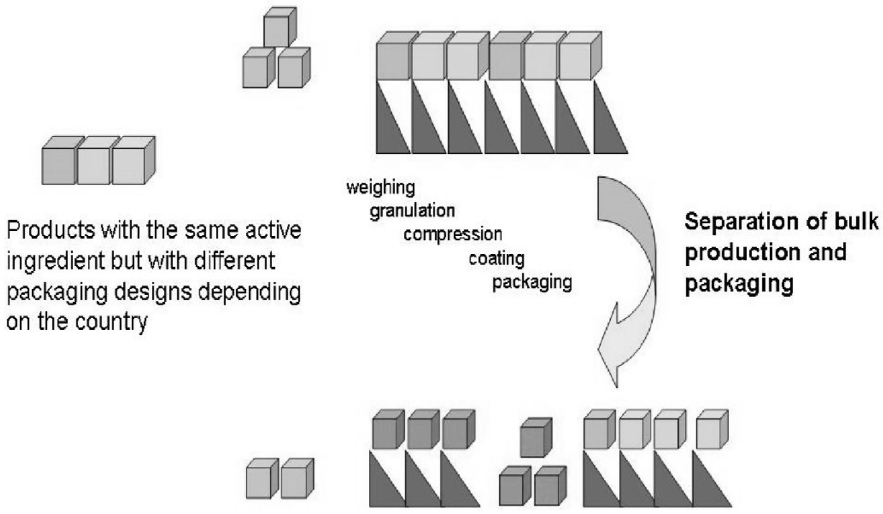

Fig. 7. Pharmaceutical finishing with an additional buffer at the stage of the formulated active ingredient

The formulation team receives the active ingredient, in two containers and keeps a buffer of three additional containers ready. New active ingredients are ordered when this buffer falls short.

The "packages on the escalator" are fairly similar and will be standardised to a large extent in the future with the aid of technical measures.

Possible solutions include the following:

- multilingual design
- the use of technologies that could integrate the printing processes for packaging material and information leaflets into the production process or be available "on time" from stock compartments.

Alternatively, another buffer could be set up at the stage when the tablets have been formulated. Then, country-specific packaging can be taken from such a buffer as required by the market with the shortest possible processing time, thereby following the pull principle, as demonstrated in Figure 8.

Whether and to what extent this type of highly synchronised production is possible would depend on the type of product. In the cases where market demand fluctuates heavily, as described above, a simple synchronisation of the production processes is all that is required. In certain instances, quickly creating a dedicated product line up to the bulk-ware stage would be possible. In order to maintain enough flexibility, a production-related separation using buffers is required between the finishing components whose configuration depends on different market influences. This ensures that enough flexibility is maintained.

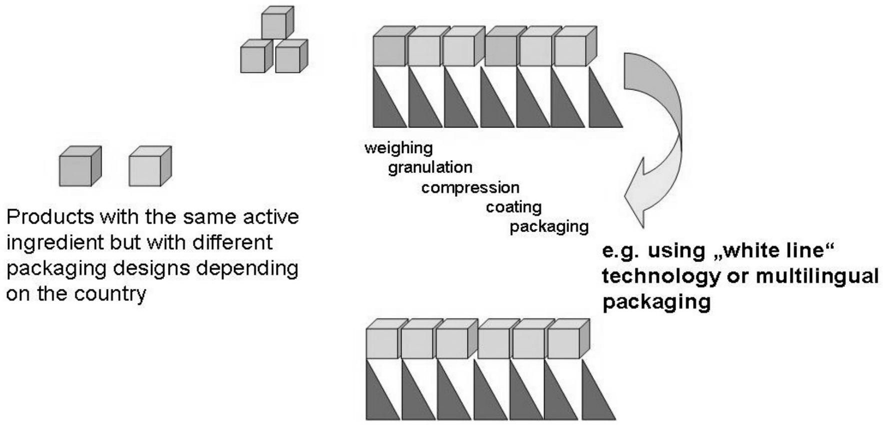

Fig. 8. Pharmaceutical finishing with technologically optimised product differentiation at the final packaging stage

In the case of a dedicated process, production planning is relatively simple for shared fabrication steps. It can be run analogous to the SCEM example of active ingredient production. The IT tools must be taken into consideration simply because the pharmaceutical manufacturer's external partners must also be incorporated into the process.

More often, however, during batch production several products are processed in one production facility. As well as the pharmaceutical product (e.g. tablets), different cardboard boxes, labels and information leaflets, together with different blister packs, bottles, etc. must be combined to make the one finished product. Supply chain management therefore does not just need to take account of the time required by the pharmaceutical manufacturer for ordering, planning and setting-up, but also the different lead times required by the production partners. SCEM, which will be discussed later, therefore also has to take the potential for disturbance amongst the various partners into consideration.

The Distribution Supply Chain

Once the finished packed product is ready, it is immediately transferred to the manufacturer's warehouse, often followed by a warehouse used by the manufacturer's national distributor, which in turn is often followed by warehouses belonging to diverse distribution companies and often than by warehouses run by the end consumers (e.g. hospitals).

This last step in the supply chain usually occurs in many organisations today during optimisation. This is how warehouses used by the national distributors are often reduced, dissolved or integrated into an overall stock system. The interface to key customers has also been optimised. However, the decrease in processing times outlined above does not yet lead to the completion of the optimisation process.

Supply Chain Event Management

Right up to the time when a product is introduced on the market, the pharmaceutical industry has invested considerable sums of money in the development of a product and has made substantial amounts of money available for production facilities and for the provision of highly qualified personnel. The market remains chaotic however, as can be seen from the examples of market influences shown above, and the customers are extremely demanding in terms of what they expect from pharmaceutical products. Suitable means in the form of optimised processes, apt monitoring, and intelligent controlling are urgently required so that the best possible gains can be made from the investments. We have already described parts of the standard procedures for the production process earlier on. What is still missing is a detailed description of the interface to the market, monitoring tools and last but not least a method for controlling the system. Before we look at controlling the entire system in the short-term, we will summarise and outline the hardware, and explain long-term controlling. In the classical model, the availability of production facilities and/or production capacities together with the quality of raw materials and intermediates posed risks at different points in the supply chain for supply chain planning (Metz et. al 2004). These problems can be solved today using two different approaches for more flexible production (Küppers 2006). These approaches will be examined with reference to control quantities for extreme long-term and short-term flexibility. After the complete model has been discussed, the procedure for dealing with disturbances in the system will be outlined.

During active ingredient production, active ingredient stocks are controlled as they were before. Like the shelves in a supermarket, stocks are continuously refilled once the reserve stock has been depleted (vendor managed inventory concept). As a rule, modular facilities are used for each active ingredient since this system is the best for short processing times (see above). The facilities are designed so that if demand increases, available reserves (e.g. additional shifts) can be deployed and an adequate amount of the active ingredient can be produced as a buffer and kept in storage until the facility can be expanded. If the suggested modular facilities are used, a new facility can usually be built within six months. Dismantling facilities and using theses modules for other productions can also be undertaken within a similar time frame. The negative assumption that two facilities must be available when a product is launched on the market remains relatively unproblematic because it has become clear that only one facility (and even then only to a certain extent) can operate at full capacity. The facility can be dismantled with moderate costs and used for other products. If too much of a buffer has already been produced, it can usually be reduced over a period of many years thanks to adequate storage life.

In synchronised pharmaceutical production, a facility is usually set up so that it can deal with new plans on a weekly basis. Facilities are operated for three to four products, which means that fluctuations up to a factor of four can usually be dealt with by the planning process. Often this affects a mixture of regional and global products. This results in additional leeway for the use of capacities through prioritisation. Building and commissioning a pharmaceutical finishing line remain a relatively long-term process (one year min.) as a result of high regulatory requirements. It would therefore make sense to consider a network of different production sites in order to cope with long-term changes in market demand. Pharmaceutical finishing usually makes use of a number of production sites worldwide for one product because of the required proximity to the market and local regulatory requirements. This means that the principle of a global analysis of the change in plant utilisation rates is extremely important. During the production of bulk ware (e.g. unpacked tablets), this should be supported by high standardisation.

The "**new**" pharmaceutical supply chain still appears to be quite clearly structured and there seems to be little need for elaborate control using tools such as SCEM. The production complexity in the pharmaceutical industry has already been detailed above (see Fig. 5). Certain aspects will be discussed in detail here. After the first finishing steps, alongside the actual product, the cardboard box, information leaflet and label must be taken into account in the logistics chain. In doing so, it should be noted that the cardboard box and information leaflet often vary from country to country. This challenge can now be dealt with relatively unproblematically through the highly flexible printing process. In an established customer/supplier relationship, printing jobs can be reorganised within a few days. The capacities and flexibility of the supplier are one of the biggest strengths of the management of events in the pharmaceutical supply chain. The suppliers of cardboard boxes, information leaflets and labels have the option of adapting their delivery power relatively easily, even when production is increased by a factor of four, because the amount to be delivered is produced on-time directly from the same raw materials (paper, dies, etc.). The situation is slightly more difficult for suppliers of the type of packaging required, i.e. tubes, bottles, stoppers, caps, blister packs, aluminium foil, etc. In certain cases (e.g. glass bottles for injection solutions), the production process cannot be switched around quite as easily. The only possibility here would be an increase in buffer capacities. However, this is undesired for reasons of cost on the part of all those involved in pharmaceutical finishing. Better standardisation and a significant reduction in the number of variants would be more beneficial here. This route has been followed by a number of companies for years, often with a different degree of resoluteness.

For the following analysis, the fact that different packages, information leaflets/cardboard boxes, etc. can lead to more than 100 different variants being produced from the one product, all of which are then potentially delivered from one site to 50 or even 100 different countries, should be considered an important constraint. Before we look at managing the supply chain on the basis of forecasts, it is important to note that these forecasts are pieced together from 50 to 100 different partial forecasts that come from the different countries involved and are therefore already considerably unreliable.

Finally, a closer look must be taken at the transport of the finished product to diverse distributors/wholesalers and, depending on the country, to health care organisations. In doing so, the various routes should be examined and optimised in terms of transport times, losses and costs.

Of particular importance in such instances is the use of IT. In order to succeed in attaining an optimal degree of flexibility at the key control stage, i.e. packaging, a network of production partners must jointly operate this production. The partners must have a **shared** understanding of the **jointly** controlled supply chain, see Figure 9, and grant each other an insight into IT systems.

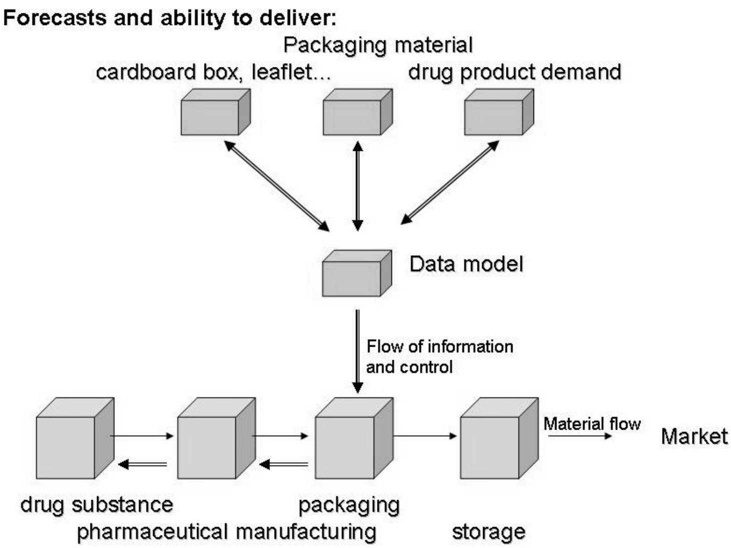

Fig. 9. Joint control using a shared data model (arrows with a single line = material flow; arrows with a double line = information and control)

By using what are known as "dashboard"-software, it also becomes possible to get a complete overview of the data from different data systems in near real time. The development of dashboard software has become relatively inexpensive, which means that with exact data and a complete overview of the supply situation planning can take place on all levels of the supply chain in near real time. The supply chain is initially controlled using the joint step of packaging. Changes here automatically lead to changes in the supply chains of the partners involved. This leads to the partners reacting to events either by making their buffer stocks available and/or adjusting their production capacities.

In pharmaceutical finishing, another hitherto often theoretical capacity reserve exists in that production here is usually run according to a two-shift rota. In order to deal with a deadline, a temporary three-shift rota could be introduced for the production process. Currently, pharmaceutical finishing, at least in Europe, is not in a position to effect a dramatic increase from two to three shift operations. Often, it is not just personnel that are lacking when it comes to finishing, but also employees' quarters (e.g. changing rooms) and infrastructure (e.g. lack of central warehousing operation). Currently, production has not yet reached the degree of flexibility that would allow it to adapt to such demands without any major reorganisation. This is something that is desired for the future and there is a chance that the boundary conditions that will make the required degree of flexibility possible will soon be created in both politics/society as well as in the economy (associations/unions).

During chemical production, it is assumed that more than one production facility exists on the one site. During holiday periods, there is often a bottleneck in terms of personnel that can lead to a theoretically unforeseen decrease in production. The possibility does exist here of refilling shared buffer stocks in reaction to an event with the help of additional personnel – either from other operations on site or if necessary additional staff.

Another technological change has been caused by the increasing use of RFID technology. Here, closed and open systems are conceivable. In the first instance, we are concerned with internal company RFID tags and also those in supplier systems that allow the exact location of products and containers to be determined at all times. Some pilot projects have already been initialised in the pharmaceutical industry for this purpose. In open systems, in contrast, consumer distribution and product authenticity are the most important factors. Despite the fact that the standardisation of reading devices, interfaces, etc. will still take another few years, the use of RFID represents enormous progress for building up networks within the supply chain (Gilbert 2004). Using RFID chips for coding will make it possible to work with real stock numbers at all stages of the supply chain without the unreliability associated with delays in data acquisition or bookkeeping errors, etc. The data model is then based on one unreliable factor only – the unreliability of forecast data on the market. This makes the system substantially less complex.

The key position is played by the cooperation during the packaging of drugs. Here, it is possible to distribute the same formulation to different markets. As well as controlling the production volume (between 0 % and 400 % if the two-shift rota is in operation), distribution to different markets represents the best lever for control. If the supplier of the packaging material and the manufacturer/supplier of the labels, information leaflets and cardboard boxes in particular, together with the pharmaceutical manufacturer, have a good insight into the supply situation of different national distributors, then they could control the fabrication process at this stage with little effort and ensure that each individual country would always be provided for (Pelzer 2004). The manufacturer also has the option of controlling the finishing process and all of the succeeding steps in the supply chain.

In terms of planning, a difference needs to be made between a number of planning levels:

- planning over a number of years for the evaluation of trends and preparation for investment decisions,
- planning for one year approx. for the acquisition of facilities,
- planning over months/quarters for the controlling the subsequent delivery of the active ingredient, monitoring buffers, etc., and
- planning on a weekly basis for finishing, packaging and distribution.

For this approach, forecasts must be generated for time cycles of 1+2 months, 6 months, 12 months and 24 months. An overview of the time scales is given by Figure 10.

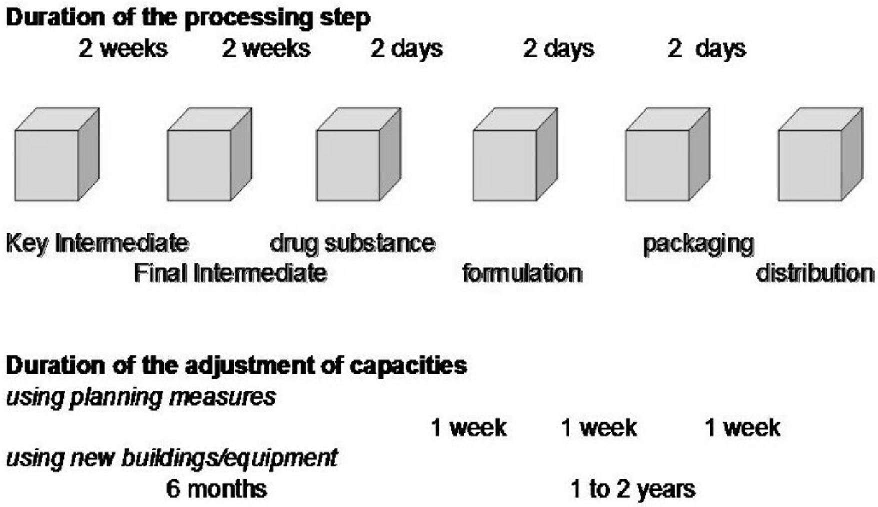

Fig. 10. SCEM time scales: Controlling possibilities in the supply chain

SCEM software looks after the following well-known tasks (Ijioui 2006):

- monitoring substance mass flows in the supply chain and monitoring buffer stocks,
- optimisation and control of short-term planning for the last step in the supply chain, packaging and distribution. And also the supply of orders for printing (labels, cardboard boxes and information leaflets) and ordering packaging material,
- informing SCM management of disturbances that could not be corrected by the system through self-optimisation,
- logging forecasts, evaluating input on the basis of historical data and creating overall forecasts, as well as,
- simulation of funding and long-term development in order to prepare for investment decisions.

Disturbances in a jointly operated production step can be manifold. This can occur as a loss of shipment due to machine failure in one of the partner companies or as a result of disruptions during data transfer. Joint planning therefore also has to take account of joint cost planning and sequence scheduling. A good example of this is the comparison of the is-situation with the optimal situation for the total costs associated with a job (Küppers a. Kuhn 2006), as demonstrated in Figure 11.

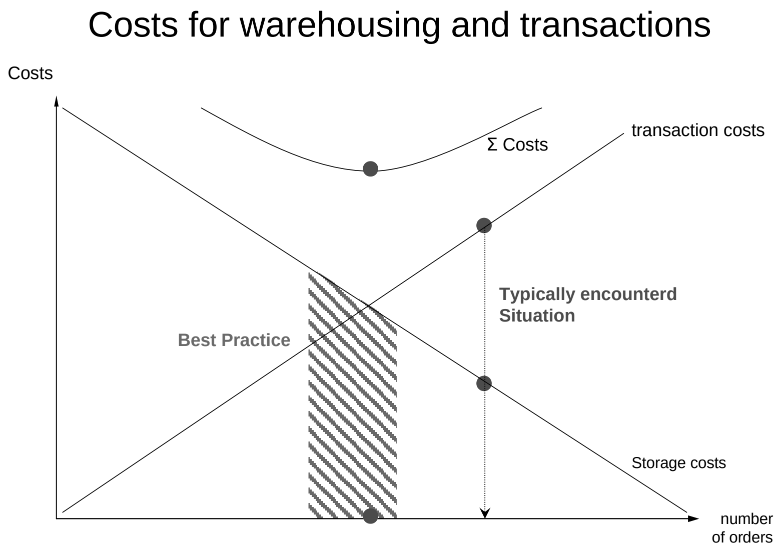

Fig. 11. Representation of the cost situation for delivery in pharmaceutical finishing/ packaging as a comparison between "is" and "should be"

Very often transaction costs are underestimated because they are usually not visible directly. In contrast, storage costs tend to be overestimated by pharmaceutical companies and the decision to destroy surplus material (e.g. cardboard boxes) is often a difficult emotional one. Thus a clearly suboptimal overall situation arises in most cases (Küppers, Ewers, Kuhn 2006).

SCEM attempts to automatically cover certain cases, while others have to be solved "manually" by all of the partners together. Computer systems could provide warnings here. Typical examples of problems to be dealt with either automatically or manually include the following:

- When planning, a 10 % approx. remainder of stock is calculated for cardboard boxes. When the cardboard boxes are unpacked in the warehouses of the pharmaceutical manufacturer, a package with 15 % of the cardboard boxes required is damaged. Since each package is equipped with an RFID chip, the shortfall is automatically recognised by the system when the cardboard boxes are transferred from the warehouse to the production line. Since it was manually entered into the system in the warehouse that one package had been damaged, the system can therefore automatically generate a repeat order using both pieces of information.

- When they undergo an approval test, one barrel out of five containing cornflour fails to meet the approval criteria due to an excessive amount of ethanol. Analytics receive an order from the system for a new more in-depth inspection incl. taking new samples; at the same time, the system informs the head of operations about a possible production bottleneck before the end of the following week of production.
- A blister-pack facility operates around the clock on the basis of a three-shift rota. As a result of this ongoing job order structure, it is impossible to service the facility. The RFID tags, which are built into the size parts, saves the lifting rates of the stations and uses the mean time between failures (MTBF) as a basis for notifying the central size part warehouse when the blister punch, for example, needs to be replaced. This allows the punch in need of service to be replaced with the repaired punch during the next order change and prevents the quality of the blister-pack production from being affected. As soon as the new punching tool has been installed, sensors automatically check the packaging equipment to ensure that the correct size parts have been installed for the follow-up order. The facility can then be re-started. Unexpected stoppage can be avoided.
- Despite this, a packaging line still breaks down. The packaging machine's control system automatically sends the facility error report to the service division and/or manufacturer of the facility and to the SCEM system. The SCEM system automatically generates a message and sends it to the head of operations (and copies it to all of the cooperation partners) with a list of delays and bottlenecks associated with the breakdown over a period of one day, one week, two weeks, and makes appropriate planning suggestions with initial cost estimates.

Summary and Outlook

Over almost 150 years, the pharmaceutical industry focused on the one single aim of developing principles for healing illnesses that were still untreatable at that point in time. Only during the 1960s the concept of imitating products (known as generic pharmaceuticals) and then selling them at cheaper prices come into being. Only in the 1990s an increasingly noticeable cost pressure on drugs originate as a result of the visibility of changes in the age pyramid began. The pharmaceutical industry has since reacted to these influences.

The pharmaceutical industry has made significant progress at different points in the supply chain over the past few years, e.g. in terms of the integration of suppliers, the transparency of the supply chain, and concentrating on the market. In many cases, quality and costs have not yet been harmonised. The conditions required for hardware have been established to a varying degree by the different companies. In some companies, the concept of the modular facility for the production of active ingredients is already quite advanced. A number of pharmaceutical companies have established one of the concepts described earlier for formulation and packaging. The hardware required for a new pharmaceutical supply chain is theoretically available. It is only a question of time until the hardware also becomes available in reality for directly controlling the pharmaceutical supply chain on the basis of market demand. As stated elsewhere (Küppers 2006), the pharmaceutical supply chain will undergo a complete modernisation process over the coming ten years. It is assumed that the majority of active ingredients will then be produced centrally (to a large extent in Asia). Finishing, packaging and distribution will be organised on a collaborative basis in each of the markets according to local criteria. The practical exploitation of potentials will also have undergone significant progress by this time thanks to the integration of IT. Along with RFID technology, the authors foresee a powerful and efficient SCEM, in particular, being used as a tool for this process. Just as in other places, progress here has yet to be fully realised, however the potential for progress is discernible and this alone should ensure the success of the approaches.

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Event Based Process Performance Management

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Introduction

An important element of Supply-Chain event management is the event-based measurement of the Supply-Chain performance which is enabled by new IT systems. Implementing these systems also leads to changes in the measurement system.

The transition from transaction-based to event-based systems opens a new way of managing Supply-Chain processes. Information pull can be replaced by a push of information in process monitoring. This push of information can be integrated into event-based Supply-Chain management information: Instead of checking the performance in irregular intervals, the system informs managers and process owners through alerts about states of emergency and necessary action. Supply Chain event based performance management allows Management by Objectives and Exceptions (MBOE) philosophy.

Additionally, instead of weekly or monthly or quarterly reports, notification are generated on a real-time basis: Instead of waiting for a report, the information is processed at the time of the event and is immediately passed on to the people responsible for action. This new closed–loop control system replaces the open-loop control mechanism of existing, non event-based Supply Chain IT systems, and aids in managing a process within predefined borders.

However this management philosophy requires a radical change in thinking: It requires a clear differentiation of the normal state from special cases, which require an immediate intervention by management or process owners. As long as business is running as usual within the predefined borders, no intervention is necessary. When the process deviates from the defined/described path, the event-based system can deliver a regular message about the type and size of deviation: The system constantly provides information about possible out-of-control states and, if implemented correctly, asks the persons responsible to perform the necessary actions to bring the process back under control.

Deriving Suitable Metrics from the Supply Chain Strategy

The Supply Chain strategy describes how a company wants to achieve competitive advantages from its Supply-Chain performance. Does a company gain the upper hand in the market through better delivery times than those of the competitor? Do customers expect additional services with the product delivery? These are examples of typical questions within the scope of the strategy development:

- Which make/buy mix is necessary to satisfy the market?
- Which scale effects are necessary to compete?
- Which production and distribution infrastructure should be used?
- What decision rules are required and need to be implemented?

To define a Supply-Chain strategy, the company needs to first analyze customer requirements and benchmark their own process performance with their competitor's. Based on these facts the company can decide on how to successfully achieve a competitive position.

Customer requirements for the Supply Chain performance must be captured in detail. While the requirements for product characteristics are usually documented very well, many companies do not know the detailed customer requirements for Supply-Chain processes. A typical question during the assessment of the customer requirements is: How do customers value a shortening of the order fulfilment lead-time versus an improvement of on-time delivery? To determine the customers' needs, interviews of the main customer groups are necessary, because this information must be gathered as directly as possible.

The Balanced Scorecard published by Kaplan and Norton (Kaplan & Norton 1997 originated as a result of the dissatisfaction with traditional financial reporting systems. The Scorecard values monetary and non-monetary, operational and strategic metrics, as well as late and early indicators at the same time. Thus the management receives an overall view of different perspectives of the actual business situation.

The Balanced Scorecard (BSC) is a management system for the strategic leadership of a company with a metrics system (Gehringer & Michel, 2000). It has several different perspectives, e.g. customer, process, growth and finances, with early indicators and the representation of the root-cause relations. The scorecard serves as an overview at all levels of the operation and for strategic feedback. The conversion gap between company strategy and daily business operation is minimized through use of the scorecard. Four classical perspectives described by Kaplan and Norton are:

- **Finance and economic perspective:** In the finance perspective, an overview about the financial situation is given. The finance view is always connected with the company's profitability: it displays the financial success of a company. The finance perspective can support strategic decisions such as remaining independent, achieving profit goals, reducing costs, and improving cash flow.

Typical metrics are company capital asset turns, operating profit, liquidity, and gross margin.

- **Customer perspective:** In the customer perspective, metrics are illustrated in relation to customer and market segments, e.g. customer satisfaction or market shares. Moreover, companies review the essential metrics, highlighting relations with external partners in the customer perspective, such as the development of customer relations, customer connection, and the integration in the customer process. Typical metrics include the remaining life cycle of the products, new customer turnover rate, and the turnover rate of the top 10 customers.

- **Internal process perspective:** With the internal process perspectives, the company demonstrates innovation capabilities as well as fulfillment of the process requirements. Strategic purposes can be, for example, improving process quality, shortening process time, or increasing on-time delivery, quality and dependability. First pass yield, order fulfillment lead-time, on time delivery and forecast accuracy are typical metrics.

- **Learning and growth perspective:** In the learning and growth perspective, companies measure their employees' potential and motivation. The main focus is on how the company can adapt itself to the future. A company may strive to achieve leadership in technology, for example, or a high employee satisfaction index. Some typical metrics are new product turnover, number of advanced training days, number of improvement projects, fluctuation, and absenteeism.

The purpose of the Balanced Scorecard is to have a system to diagnose strategic decisions, to make a company's objectives and strategies measurable, to communicate targets, as well as to plan and to monitor. Integrating the whole company and all employees in these processes is vital for the success of managing a company through a balanced scorecard.

Each company requires an individual Scorecard, because each company has individual strengths, weaknesses and specific objectives. A company must find suitable metrics for the perspectives which match the company strategy. It is a matter of implementing the existing strategies and not of developing new strategies.

The Balanced Scorecard has been recognized as an aid in the complete assessment of company achievements by considering all metrics at once, rather than focusing on single ones. The different perspectives are useful in monitoring the whole assessment, as they assess all important criteria and points of view.

The scorecard can be adapted to an event-based performance measurement of the Supply Chain. An event based scorecard consists only of early indicators, because most events require timely reactions.

However, the classical four perspectives are not sufficient for the management of supply chains, because they were developed mostly for non-producing companies. A complete supply chain consists of material, information and value streams, from the supplier to the customer, and from the identification of market demand to the fulfillment of an actual order (Becker, 2005). An essential aspect in Supply

Chain Management is process orientation, which is evaluated by the process perspective of the Balanced Scorecard.

In the Balanced Scorecard, suppliers are not taken into consideration, although they are an essential part of the Supply Chain and have great influence on the Supply Chain performance. Hence, the suppliers are to be integrated into the scorecard (Fig. 1), and are added as a separate perspective.

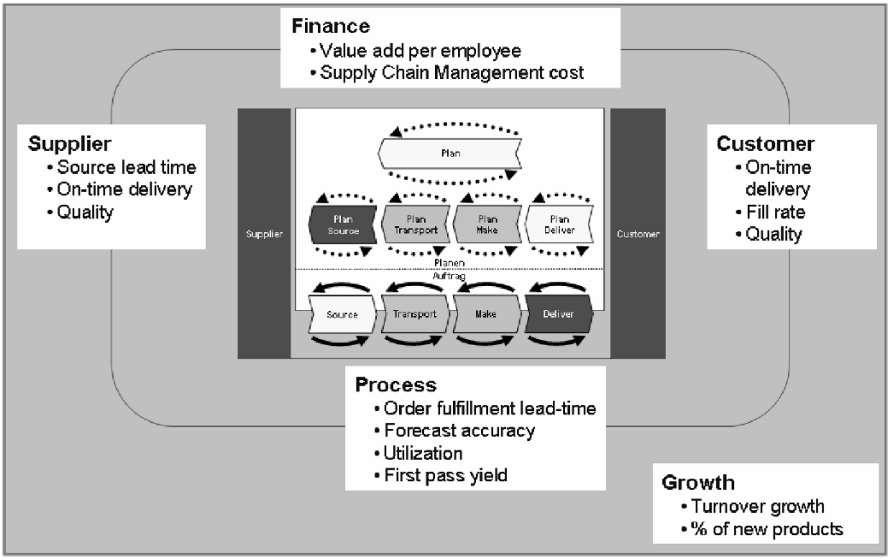


Fig. 1. Balanced scorecard for supply-chain purposes

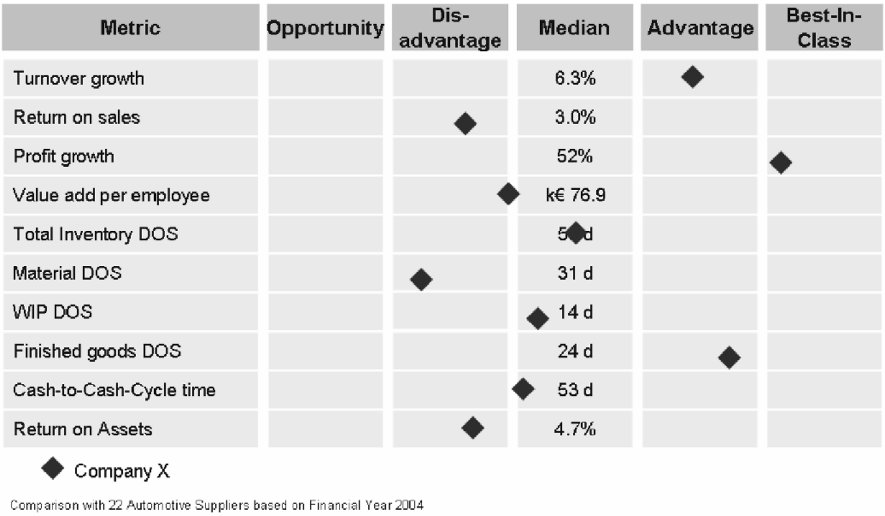
An essential problem of the event-based Balanced Scorecard is reporting the results. Many companies manage their Balanced Scorecard with numerous spreadsheet-based metric diagrams. The scorecard overview is a demonstration of the most important metrics and their actual values, often with a traffic light representation to denote the status. These lights differ according to performance level:

- Red - objectives not achieved;
- Yellow - objectives partially achieved; and
- Green - objectives achieved.

Other companies use a cobweb representation to show the metrics and their objectives.

While the Balanced Scorecard requires an unambiguous definition of the metrics used, the event-based Balanced Scorecard needs to maintain trigger points for notifications and their receivers. These trigger values can be determined from internal measurements or through quantitative benchmarking.

The Supply Chain Operations Reference-model (SCOR), which has been developed by the Supply Chain Council, has extended the scorecard with a benchmarking component (Fig. 2). The selected metrics are displayed with quantitative comparative values, and the results are shown in comparison to other companies. The percentile distribution of the comparative values denominates the value axis. The arrangement of a company in the classes Best-In-Class, Advantage, Average, Disadvantage and Major Opportunity indicate how the company performs in comparison to its competitors. Based on these analyses, suitable objectives and actions can be defined. However, the classes can also be used as trigger points in event control: If the actual value for a desired objective falls below the lower class limit, a warning is issued. The control mechanism on this grid may be determined by using class borders. The frequency of warnings should be reduced to emphasize out-of-control processes. If actions can't be initiated or implemented, frequent warnings may result in non-observance, annoyance and frustration.



Metric	Opportunity	Dis-advantage	Median	Advantage	Best-In-Class
Turnover growth			6.3%	◆	
Return on sales		◆	3.0%		
Profit growth			52%		◆
Value add per employee		◆	k€ 76.9		
Total Inventory DOS			5◆d		
Material DOS		◆	31 d		
WIP DOS			◆ 14 d		
Finished goods DOS			24 d	◆	
Cash-to-Cash-Cycle time			◆ 53 d		
Return on Assets		◆	4.7%		

◆ Company X

Comparison with 22 Automotive Suppliers based on Financial Year 2004

Fig. 2. Scorecard derived from Benchmarking

With event control, the company does not need to monitor whether the improvement measures are effective. The event based scorecard system identifies whether the actual performance moves in the direction of the objectives, and whether the actual values are better than the initial values. Since the trigger points can be either adapted to an improved situation or reset to take into account temporary changes, triggers can effectively support the company's objectives. As long as everything runs according to the plan, the system remains quiet. A trigger is only generated when objectives are not achieved, or when deviations occur. The trigger will result in the necessary actions to rectify the situation.

Kaplan and Norton called for the use of early indicators in the Balanced Scorecard. While a classical scorecard can exist with trailing indicators, it is of utmost importance to use early indicators for the event-based scorecard, as long-term trends cannot be reached by short-term observations. While small deviations require limited actions, projects are necessary for bigger deviations. Hence, other than operational metrics, various metrics are also monitored. These metrics which are reviewed less frequently, though with the same intensity.

Besides daily operational performance measurements and monthly metrics - the actual status of the management system – some metrics should be used for reviewing expected performance for the future. For existing and planned improvement initiatives, more metrics should be applied. Hence, it is advisable to replace the standard single scorecard with four different ones, each observing one aspect of the Supply Chain (Fig. 3).

The first scorecard shows the current operational performance. This data changes by the minute. When deviations occur, a trigger is promptly generated and short-term measures can be initiated to improve the processes or to avoid a negative trend of a metric. The data is up-to-date – not older than a day – and trends can be identified very quickly, enabling the identification of deviations and appropriate triggers. Small improvements are introduced, unless there is a large performance gap, in which case a project may be started.

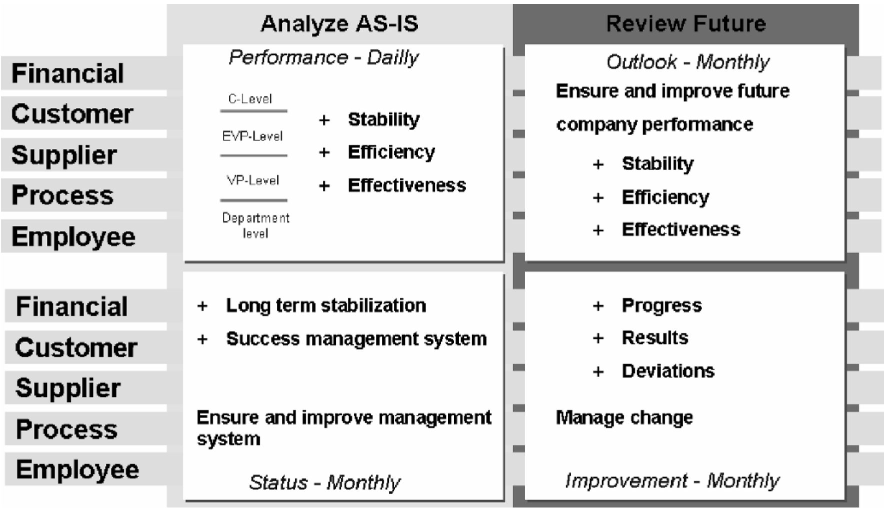


Fig. 3. Display of four scorecards

The second scorecard shows a regular status overview. In this view, monthly updates are shown for important metrics. Financial metrics can be also integrated into this monthly view. With this scoreboard, the structural changes that influence the Supply Chain are pursued. These metrics should be reviewed once a month.

The third scorecard describes the next month or another defined time period in the near future. The predicted sales as well as the influence of the product development on the Supply Chain are considered. According to the frequency of data update, these Scorecards are reviewed half-monthly or monthly. As the data for these metrics is not 100% certain, it enables quick reactions to changes. If sales threaten to falter or a considerable sales increase is predicted, the supply chain can be adapted before the event takes place, thus enabling the Supply Chain to deal with the new situation directly.

The fourth scorecard summarizes the improvement initiatives in the Supply Chain and shows important metrics of the actual improvement initiatives in an overview. Metrics for the view are updated weekly and serve as a guideline to the project team for the assessment of the project's success. The project manager, project sponsors and other stakeholders are immediately informed of deviations. With these four aspects the Supply Chain can be valued as a whole and the performance event-oriented can be achieved. Beside a daily assessment of the actual performance, changes can be valued weekly or monthly. Triggers are set off and automatically and push the process owners to initiate measures to react to deviations.

Design of a Metrics System for Event Monitoring

For Supply Chain management, numerous metrics of different uses are known. For a Balanced Scorecard, metrics with different perspectives must be taken into consideration. In books on Supply Chain management, some metrics are defined for the Supply Chain. A leading source for these metrics is the Supply Chain Operations Reference model - "SCOR" - (Becker a. Geimer 2001). With every new edition of the process reference model, the metrics are slightly changed, but the basic structure remains the same: Operational, status-related and financial metrics are mixed.

The following paragraphs will show what considerations are necessary to successfully introduce event based metrics, using two metrics. Metrics drive behavior, and hence have to be determined in such a way that the right behavior is produced.

On-time Delivery

A classic subject in the Supply Chain is on-time delivery. Many companies use this metric to evaluate customer service and customer satisfaction. On-time delivery states whether a company manages its Supply Chain efficiently to implement the customer-required or promised delivery dates.

To monitor on-time delivery, several different measurement issues need to be resolved. What is the definition of on-time? Which dates are used, the confirmed date or the customer request date? How are early and late deliveries viewed? Which tolerances are used? How do companies evaluate changes of the customer request date?

First of all, the accuracy of on-time delivery needs to be defined. According to customer requirement or company performance, measurements can be taken in weeks, days or by the hour. Will complete orders, order positions or the numbers of items delivered be used for the measurement? For partial deliveries, it is important how the shipment is viewed; is only the missing part viewed as late?

Also, the due date must be defined, so that there is a reference for the metrics to be measured from the customer's perspective, the measurement of on-time delivery in relation to customer request dates shows the most important information, however this measurement is not commonly taken in companies. Either the customer request date cannot be entered into the IT systems, or it is not entered precisely enough with the order input. The decision to base measurements on the on-time delivery date rather than the confirmed date must also be made. In addition, the customer delivery must be determined exactly with the definition. Does the date signify that the product is ready for sending, handed over to the carrier, or is it the date that the customer receives the product? If the customer requests to pick up the product, is the date on which the product is available or the date it is collected noted?

Many companies must also clarify how rescheduling the order at the customer's request is to be considered in the calculation. However, frame contracts, call-offs and regular bulk shipments to subsidiaries need to be viewed differently and may have a different definition of on-time.

Many companies that emphasize on on-time delivery, measure against the customer request date. They measure the receiving date at the customer on a daily basis and evaluate early and late deliveries as not on time. The definition correlates with the achieved on-time delivery: The less forgiving the definition is, the better the on-time delivery that results. Companies with the most rigid definition of the metric often have a clear advantage in terms of on-time delivery, as compared to their competitors.

In event based control, evaluating every delivery is vital. For any delivery time of delivery must be determined. If the on-time delivery drops below the defined threshold, the root causes must be found immediately. Immediate action is vital to avoid more severe problems.

Inventory DOS

A second important Supply Chain metric, inventory Days Of Supply (inventory DOS) provides a good picture of the Supply Chain efficiency. Beside the absolute inventory value, inventory turns and inventory DOS are frequently used metrics. The inventory value is not suited for benchmarking different supply Chains of companies or locations. Instead, inventory turns are often used. However, the inventory turns metric can only be determined with difficulty for different inventory steps. Hence, for the Supply Chain consideration, the inventory DOS has been widely adopted as best suitable metric. This metric can easily be calculated for the whole supply chain as well as single inventory positions. Simplistically spoken, the inventory DOS shows how many days the supply would last without new deliveries to keep up with current sales, assuming that the inventory structure is correct – meaning the necessary parts are in stock. The lower the inventory DOS, the better the Supply Chain performance is.

To calculate inventory DOS properly, basic stock values must first be defined. Most companies book their inventory on Cost of Goods Sold for finished articles and semi-manufactures or material costs. Hence, to be valued as an approach for the total inventory DOS consideration, the total material, semi-manufactures and finished articles, including slow and non moving materials, parts and products based on the quantity in stock and the cost of goods sold, are used. This is the actual inventory value. For operational consideration, inventory depreciation is not to be taken into consideration.

To avoid comparing apples and oranges, Cost Of Goods Sold is used as a reference value for consumption, rather than the sales price – which is used normally for inventory turns calculation. If sales prices are used, distribution surcharges and administrative surcharges as well as the profit margins are included, which leads to a distorted inventory performance picture. Using Costs Of Goods Sold, the inventory DOS can be derived much more expressively and also be calculated within single digits, enabling the differentiation between the inventory quantity and the required quantity.

For an event-based Scorecard, the inventory DOS can be used to check both changes in the demand and poorly arranged basic material.

Choosing the Right Metric

For event-based supply chain monitoring, the chosen criteria affects the metrics. These metrics must fulfill the requirements of traditional reporting, but need to fulfill extra requirements concerning event orientation. Good metrics for a conventional reporting are characterized as follows:

- unambiguously defined,
- accepted by everyone in the company,
- expressive,
- reproduce able,
- regularly reported,
- purpose-oriented, and
- decision-supporting

The definition has certain requirements that must be fulfilled; the definition encloses all important descriptions and is agreed on by all stake holders. The definition contains who is responsible for data capture as the metric is being calculated, which reporting is needed, and the routing of the reports. Hence, the following rules apply to these metrics:

1) The metrics must have clear definition
2) The metrics must have defined target values

3) No metric acceptance without evaluation
4) No metric evaluation without actions

While these metrics provide information as well as decision support, immediate action is the most important reason for implementing elaborate metrics systems. Actions can be determined immediately from the timely reporting of the information.

The successful application of event-oriented measurements leads to the introduction of a closed control loop. With the measurements, the actual values are captured. If the actual value deviates from the defined target values and the agreed tolerance, a control trigger is sent to the process owner to alert a responsible person about the situation. Now this process owner can react using different approaches and thus compensate for the disturbance as quickly as possible. Under these circumstances, two scenarios exist:

1) If the intervention was successful, the target value is reached: The process is again under control and no new triggers are sent out, while the process is in control.
2) If the intervention was not successful, there may be several causes: Either the action was not effective or a wrong activity was initiated.

In the second case, the system can destabilize itself, e.g. the process can become unstable by faulty reactions, causing wrong or faulty settings to be carried out. When this occurs, the event management quickly leads to an irritant flood of triggers, and numerous alerts appear, to which the process owner cannot react in time. In both scenarios this leads to a non-acceptance and disregarding of the incoming alerts; the generally helpful information is of no use, because the person responsible suffocates in a flood of information, and finds insufficient action possibilities during the given response time.

The process and its main influence dimensions must be understood, and a measure bundle must be defined possibly with effect. For every deviation, the possible measures which bring the process quickly under control must be identified. These measures must be effective within a short period and work short-term. In order to initiate the actions, the process owner must be able to receive the necessary trigger information, and has the authority and responsibility to initiate the necessary measures.

Hence, the data for event-based metrics needs to be received automatically and transformed directly into the metrics value. The quality of the source information must be very high, because wrong data leads to bad information and false interpretations. The target and the limit values which provide information to the persons responsible for alerts are to be defined and agreed on by the stake holders.

For each alert, the process holder needs to define whether the alerts should be sent only with the first deviation, or for every consecutive occurrence of a deviation. If only special cases are to be announced, the absolute value of the deviation is important. In many cases, it is also helpful to inform the process owner about the first reentry into the desired performance. In all described cases, there must be an announcement about whether the monitoring still works, so that missing signals do not lead to the interpretation, that the process is not stopped.

In addition, the frequency of data measurement must be defined, and the metrics must be calculated. This frequency is to be aligned to the control behavior. The trigger frequency needs to be aligned to the intervention possibilities, depending on how quickly the measurable processes are adjusted, and which processes are slowly controlled.

With the introduction of even-based metrics, the process changes from a simple plan and act as a closed loop feedback, which maintains a process in a given performance range. The process thus has a high quality and stability. For event-based metrics the following rules can be defined:

1) Each metric has a feedback loop
2) Each metric has a clear definition
3) Each metric has defined target values and control limits
4) Each metric has automated capture of the underlying data
5) Each metric has an owner and assigned deputies
6) Each metric has an analysis process defined
7) Each metric has defined action possibility

These rules result in a very limited set of event based metrics to be used only in special cases. For these special cases the event based metrics enable a considerable performance improvement.

Implementing the Metrics System

To implement an event-based metrics system, the activities necessary for effective monitoring have already been mentioned above. And the following additional requirements need to be fulfilled.

After selecting the processes, the company must determine whether these processes are under control and if all influence factors are known. Event based metrics can be used to determine this, although a conventional metric is sufficient. For each process, the most important event based metrics must be selected, based on information quality. The fewer metrics there are, the easier the event control is. After agreeing on the definitions, automatic calculation of the metrics must be defined and implemented. Also, threshold values and the control limits need to be defined.

For the alerts, the persons receiving the information are must be identified, as well as the frequency and the means of communication. In many cases emails are enough, but some serious disturbances may require the sending of SMS, especially if the person responsible does not have constant access to the internet.

The process owner should learn the meaning and implications of the metrics and develop his or her action instruments in such a way, that he can react quickly to changes.

Case Study

In a customer project of BESTgroup the challenge lay in introducing a Supply Chain metrics system in a holding and several divisions of a company.
In the analysis of the existing metrics systems, many methods and practices were identified in the various physical locations. A total of more than 120 metrics with different definitions and representation forms were used. The inconsistent requirements arose from a decentralized responsibility structure and could only be summarized by extensive coordination.

Through stronger centralization and standardization of the reports, an event-oriented metrics system based on common, uniform definitions was created. A hierarchical system was developed that allowed all aspects of the Supply Chain to be viewed by different target groups, ranging from plant managers to the board of directors. The system was based on the Balanced Scorecard and included several aspects which were used for different objectives.
For regular measurements, an infrastructure was created, with up-to-date daily transfers from three different ERP systems (Fig. 4). The data were processed for graphic report. Moreover, the scorecard representation was updated daily, as well as time based charts with varying levels of detail. The results were published daily in the company intranet. Now, building on the results, alerts could be defined to call attention to any deviations. Therefore, different rules at the different management levels could be used to fulfill the divergent demands for information, action and feedback.

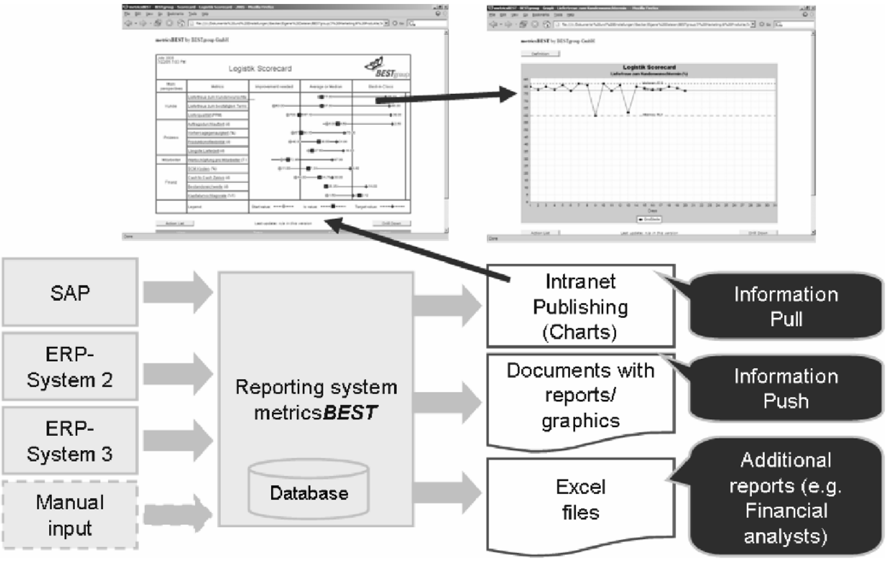


Fig. 4. Overview of the metrics reporting system

Dealing with the Metrics

Event based metrics require a new understanding. The metrics should indicate not only the actual situation, but pursue fast changes and uncover deviations. All metrics must be trusted. The metric must be determined reliably and be reported unambiguously as well as being reproduce able. Also, the target value and the control limit values for the determination of the triggers must be agreed on by all partners. Problems can be solved only if there is a common understanding.

However, to successfully apply this metrics system, it is important to build up a metrics culture. This culture must not only consider the figures, but also value improvements, and praise successful project managers. If the events and alerts are used only to search for culprits, the new measuring system will not contribute to better performance.

Applying an Event Based Metrics System

Event-based metrics systems are a helpful complement to existing traditional metrics systems. Different metrics systems serve different requirements which vary in the scope and usage of metrics.

Not all metrics can be evaluated as event-oriented, nor can all be investigated. With their high explanatory power and the quick reaction possibilities, operational metrics are suited for processes requiring quick stabilization of performance. For many metrics, the risks of over-reaction exist: A nearly-stable system in imbalance can be brought out of control by frequent, untimely and wrong interventions.

Event orientation is also not suited for the assessment of long-term trends which creep into processes and require substantial corrections. Hence, the event control is an important aid for daily business to react to disturbances and to smooth over short-term variations. As a supplement to a conventional metrics system aimed at trend and status observation, an event-oriented system can help to better control processes by quick intervention as well as stabilize performance.

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Interfaces @ Supply Chain Event Management

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Introduction

This article examines the interaction between interfaces and Supply Chain Event Management (SCEM) systems as well as practical experiences with such systems made during the implementation of projects as well as day-to-day operations.
When writing about interfaces, it is easy to drift into an examination of the deeper technical aspects. This is not the intention of this article. Rather, it is the author's goal to share practical experiences and giving a high-level overview about how they could work. That interfaces are playing an important role in Event Management is e.g. shown by the fact that logistics fairs quite often have whole sections of the floor dedicated to them. Furthermore, SCEM implementations often have interface requirements for their implementations.
However, the knowledge that different kinds of partners have to communicate within the supply chain to make events visible, interfaces are worth thinking about, and the author would be glad if he is able to expand the knowledge of the reader in this area of concern.

Definition of an Interface – IT vs. Operations

As numerous other publications state, interfaces could have a very technical focus. The reason is often the association between the word “interface” and a typical technical IT interface like an EDIFACT IFTMIN message. But this is only one aspect. Particularly with regard to Event Management it is arguable that technical interfaces are secondary. They tend to have excellent documentation and they have already been established. It is not necessary to build them up from scratch. However, operational interfaces need to examined more closely, because at precisely these stages of the supply chain the events you want to manage are occurring. The task of the technical interfaces is then to transform the information, to transport the content and last but not least make everything transparent.

How an Interface Is Implemented – The Technical Aspects

Although technical interfaces are sometimes getting too much attention in the context of the complete process, they can make sense for processing and operating and it could occur that they become partially essential (e.g. for automated processes). Therefore the author has found that the implementation of technical interfaces could generate a risk for SCEM projects as well as causing increasing costs for the project budget. What might cause such risk? The main reasons are:

- Incomplete or badly defined requirements
- Lack of internal know-how
- Proprietary interfaces (in-house formats)
- Over-engineering – too many and too complex interfaces
- Standard interfaces which have been customised to such a degree that they no longer conform to the standard
- Usage of local standards in an international environment
- Inadequate documentation
- Insufficient testing

The implementation of such technical IT-interfaces can be done as described in the following four steps (the examples shown are from an automotive project):

1) Creation of a high-level IT landscape (Fig. 1). The main goal is to get an overview of all involved systems and applications and thus understand the data flow.

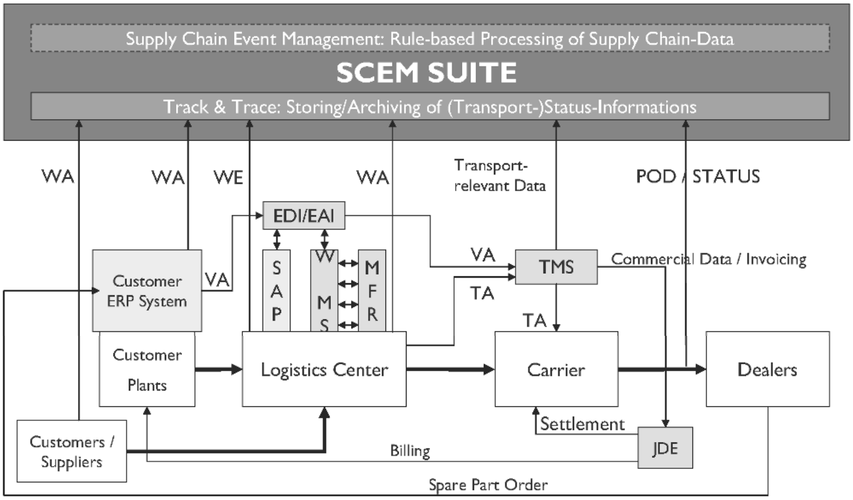


Fig. 1. Example of a high-level IT landscape

2) Developing an overview map of the interface levels (Fig. 2). This helps to gain an overview of what all the required interfaces are and how each interface has to be mapped against the other.

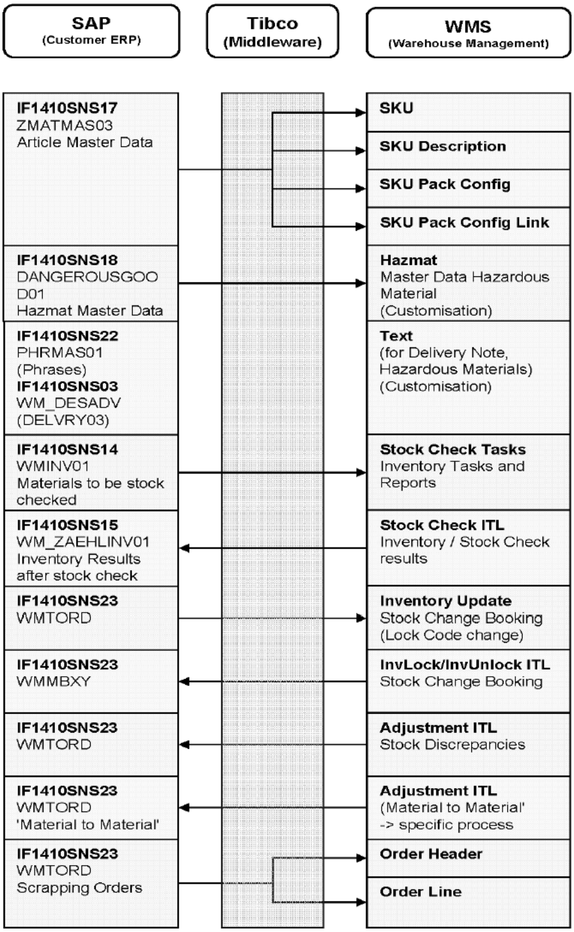


Fig. 2. Interface overview resulting from a high-level IT landscape

3) Creation of interface specifications like an Interface Design Document (Fig. 3). Based on these specifications, the interface will be developed and mapped on the field-to-field level. It should be remembered that this process can only work if all process related data in terms of content are defined. Otherwise it will be impossible to know which information must be in the interface to operate the process (e.g. whether the process requires a sales number, a gross weight, an ETA (estimated time of arrival)...)

4) Development and completion of the interface. After the initial completion, the first test messages are generated. The testing is conducted in several phases. The author recommends working through a 4-phase testing concept which consists of message testing, functional testing, integration testing and a mass test before going live with the interface. The testing phase is ended by an UAT (User Acceptance Test) with a formal confirmation of the delivery. The responsibility for implementing the UAT lies with the requesting department.

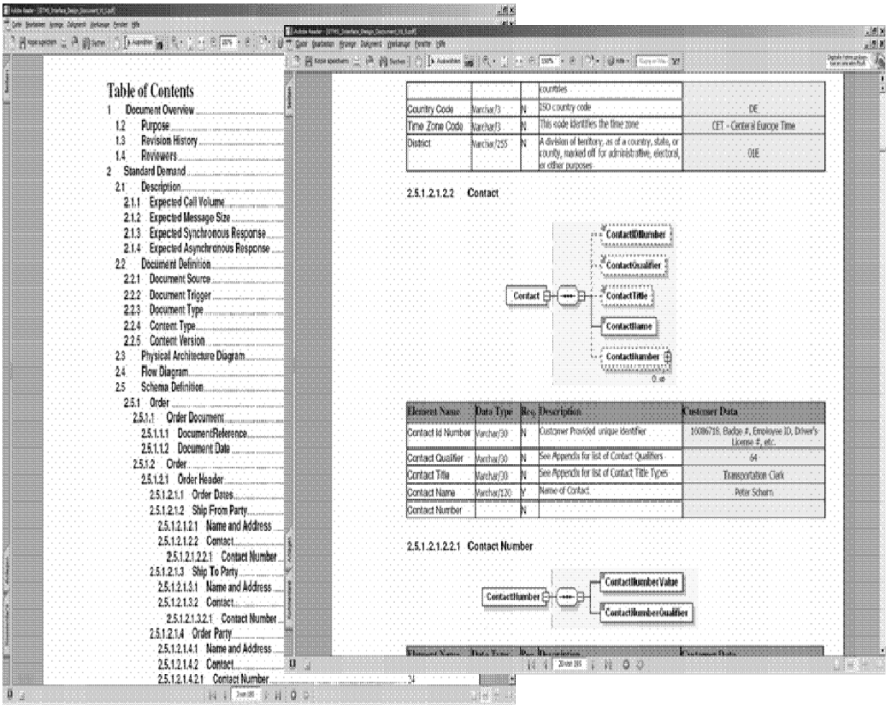
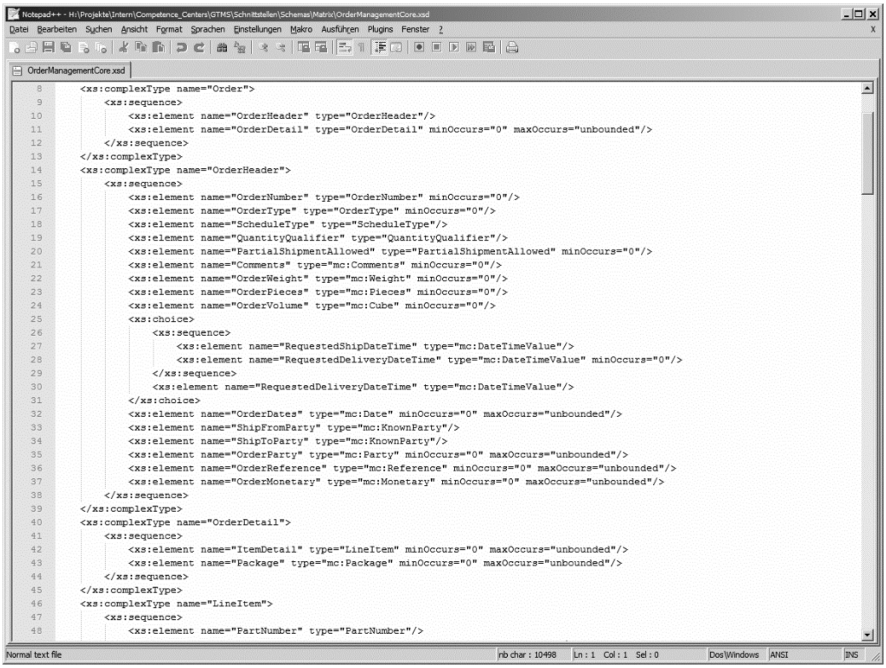


Fig. 3. Possible structure of an interface design document

After this implementation process, an interface has been created which can be used for Event Management and which fits the common understanding of how an 'interface' should look like. In this example you see an order message in XML format (Fig. 4) for sending a delivery order to a warehouse or a TMS (Transport Management System). This may be the starting point of a supply chain and the first event to be managed...



```
<xs:complexType name="Order">
    <xs:sequence>
        <xs:element name="OrderHeader" type="OrderHeader"/>
        <xs:element name="OrderDetail" type="OrderDetail" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
</xs:complexType>
<xs:complexType name="OrderHeader">
    <xs:sequence>
        <xs:element name="OrderNumber" type="OrderNumber" minOccurs="0"/>
        <xs:element name="OrderType" type="OrderType" minOccurs="0"/>
        <xs:element name="ScheduleType" type="ScheduleType"/>
        <xs:element name="QuantityQualifier" type="QuantityQualifier"/>
        <xs:element name="PartialShipmentAllowed" type="PartialShipmentAllowed" minOccurs="0"/>
        <xs:element name="Comments" type="mc:Comments" minOccurs="0"/>
        <xs:element name="OrderWeight" type="mc:Weight" minOccurs="0"/>
        <xs:element name="OrderPieces" type="mc:Pieces" minOccurs="0"/>
        <xs:element name="OrderVolume" type="mc:Cube" minOccurs="0"/>
        <xs:choice>
            <xs:sequence>
                <xs:element name="RequestedShipDateTime" type="mc:DateTimeValue"/>
                <xs:element name="RequestedDeliveryDateTime" type="mc:DateTimeValue" minOccurs="0"/>
            </xs:sequence>
            <xs:element name="RequestedDeliveryDateTime" type="mc:DateTimeValue"/>
        </xs:choice>
        <xs:element name="OrderDates" type="mc:Date" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="ShipFromParty" type="mc:KnownParty"/>
        <xs:element name="ShipToParty" type="mc:KnownParty"/>
        <xs:element name="OrderParty" type="mc:Party" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="OrderReference" type="mc:Reference" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="OrderMonetary" type="mc:Monetary" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
</xs:complexType>
<xs:complexType name="OrderDetail">
    <xs:sequence>
        <xs:element name="ItemDetail" type="LineItem" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="Package" type="mc:Package" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
</xs:complexType>
<xs:complexType name="LineItem">
    <xs:sequence>
        <xs:element name="PartNumber" type="PartNumber"/>
```

Fig. 4. Example of an already implemented interface for an order message in XML format

How an Interface Is Implemented – The Operational Aspects

The previous chapter described how a technical interface is being developed. However, without an operative process as the basis, there is no need for such a type of interface in combination with Event Management as the data to be processed by them does not exist. This is what SCEM is for: The Events which the user wants to manage have to be defined. Here we will also have to deal with interfaces, but with operational interfaces instead of IT ones. This can be illustrated with the help of the following standard warehouse layout (Fig. 5).

Pos. 1 (Fig. 5) represents incoming goods in the form of a delivery. The basis of the receipt booking might be an early recommendation which enables the goods to be processes in a warehouse management system (WMS). A fax may also be an alternative for the receiving process. In any case, there is an interface at this point in the form of a process transition – in this case between the delivery and the receiving party. This is what the author calls an operational interface.

Pos. 2 (Fig. 5) represents the warehouse area. Here material is moved via conveyor technology from one warehouse area to a consolidation / deconsolidation zone. Here as well an operational interface becomes obvious when, for example, at the end of the line a worker has to pick up a container from the conveyor facility and instigate a scanning process.

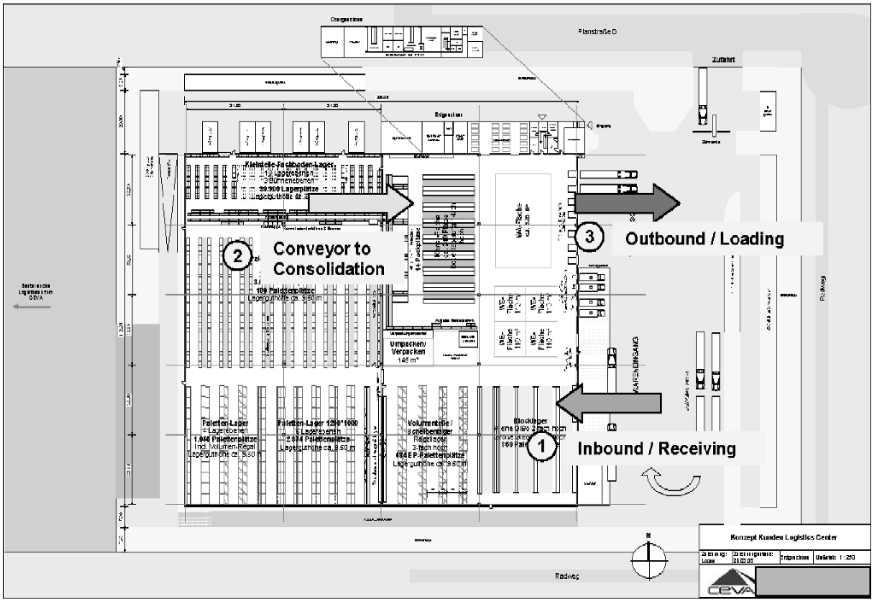


Fig. 5. Warehouse layout with typical process stages

Pos. 3 (Fig. 5) is the opposite of pos. 1 – that is to say, it represents outbound goods within the dispatch process. Here, an operational interface might be the generation of the necessary shipping documents or a loading scan on the vehicle.

This way of looking at the process chain may be continued throughout the whole Supply Chain, for instance by tracing the transport from the warehouse towards a HUB, a plant, or a dealer. For each of the events mentioned a status can be established. Nevertheless, technical interfaces are not necessarily needed in order to enable these procedures. However, if processes can be made more efficient or safe, the use of an IT interface is possible or even necessary.

This example was chosen to show that the use of a technical interface is based on the operative process and consequently the operational interface. In connection to Event Management it is arguable that nearly every event represents an operational interface.

Conclusion

There are interfaces in both technical and operational environments. The operative process with its requirements is the basis for the use and contents of an interface. In connection with SCEM the operational interface is the event which can be controlled. For management concerns technical interfaces are normally used.

- Interfaces are not a pure IT subject

- There are interfaces in all parts of the process chain
- Every interface is based on the process
- An event is an operational interface
- Any event can be managed by means of technical interfaces

Interfaces within a Supply Chain – Examples & Standards

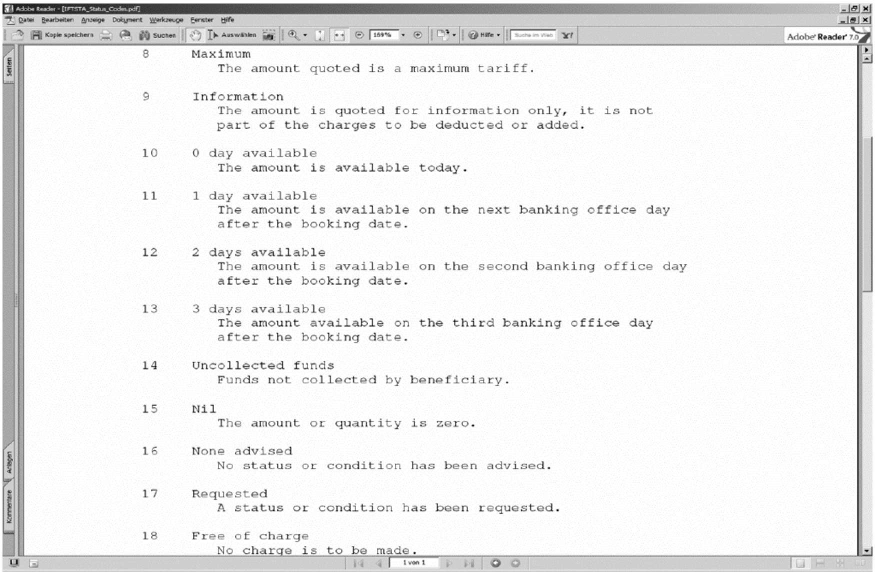
So that a supply chain and the possible events within it can be managed, the use of interfaces in it is advisable. Those interfaces do not necessarily have to be newly developed as there is a variety of already existing national and international standards as well as standards within a certain sector of the industry. Depending on individual requirements and involved partners, you may have access to ready-made solutions out of a ready-made toolkit. Unless otherwise required, the author would recommend the use of international standards due to the fact that the supply chain likewise operates across borders.

In this chapter the author will show several examples of such standards.

Standard IT-Interfaces

Widely known standards being used for technical interfaces as well in SCEM are for example:

- EDIFACT / EDIFOR (international)
  - Electronic Data Interchange for Administr., Commerce and Transport
- Odette (international)
  - Organization for Data Exchange by Tele Transmission in Europe
- ANSI-X 12 (international)
  - American National Standards Institute
- VDA (national, Automotive)
  - Verband der deutschen Automobil Industrie
- FORTRAS (national, Carrier, Forwarder)
  - Forschungs- und Entwicklungsgesellschaft für Transportwesen
- XML (international interface format)
  - Extensible Markup Language



```
8      Maximum
          The amount quoted is a maximum tariff.

9      Information
          The amount is quoted for information only, it is not
          part of the charges to be deducted or added.

10     0 day available
          The amount is available today.

11     1 day available
          The amount is available on the next banking office day
          after the booking date.

12     2 days available
          The amount is available on the second banking office day
          after the booking date.

13     3 days available
          The amount available on the third banking office day
          after the booking date.

14     Uncollected funds
          Funds not collected by beneficiary.

15     Nil
          The amount or quantity is zero.

16     None advised
          No status or condition has been advised.

17     Requested
          A status or condition has been requested.

18     Free of charge
          No charge is to be made.
```

Fig. 6. Excerpt from an IFTSTA status message description

Here we are shown an interface which is widely known in Event Management and which is a medium for transporting status messages in connection with the respective reason codes. In the above example several status descriptions are shown with the associated qualifiers and codes (Fig. 6). In order to permit the transportation of such messages it is necessary to develop an appropriate infrastructure. Of course, adequate standards are available for that purpose. Concerning the selection and implementation the infrastructure is of lesser importance than the decision regarding the interfaces planned. In this context, typical ways of communication are:

- OFTP / FTP
- HTTP / HTTPS
- ISDN
- Mailbox

Interfaces Related to Business Processes

As mentioned previously, the precondition for using interfaces is always an existing operative process. In the following list, business processes are shown in an exemplary way linked to possible interfaces (Table 1). In this connection, it is useful to map the interfaces on the basis of the above-mentioned standards. Here the international standard EDIFACT and, alternatively, local messages such as VDA and FORTRAS were used.

Table 1. Overview of business processes and available standard interfaces

Business Process	Standard Message Type
Load Tender / Pickup Request	VDA 4921 - EDIFACT IFTMIN
Bordero	BORD128 - EDIFACT IFCSUM
Status	STAT128 - EDIFACT IFTSTA
Loading / Unloading	ENTL128 - EDIFACT IFTSTA
Delivery Note	VDA 4913 - EDIFACT DESADV
Inventory / Stock Report	VDA 4913 (EDL-operation) - EDIFACT INVRPT
Receipt Notification	VDA 4913 (EDL-operation) - EDIFACT RECADV
Shipment Notice	VDA 4913 (EDL-operation) EDIFACT DESADV
JIT (just-in-time)	VDA 4916 - EDIFACT DELJIT

As can be seen, a standard interface is available for each business case. Knowing this, it should now be possible to realize Event Management by with the assistance of IT interfaces.

Transport Flow Supported by EDIFACT Messages – An Example

In the above-mentioned example it was pointed out that in general there are technical interfaces available for existing business processes. In this section the focus is on one complete process and showcasing its details, namely the complete support of transports via EDIFACT messages (Fig. 7).

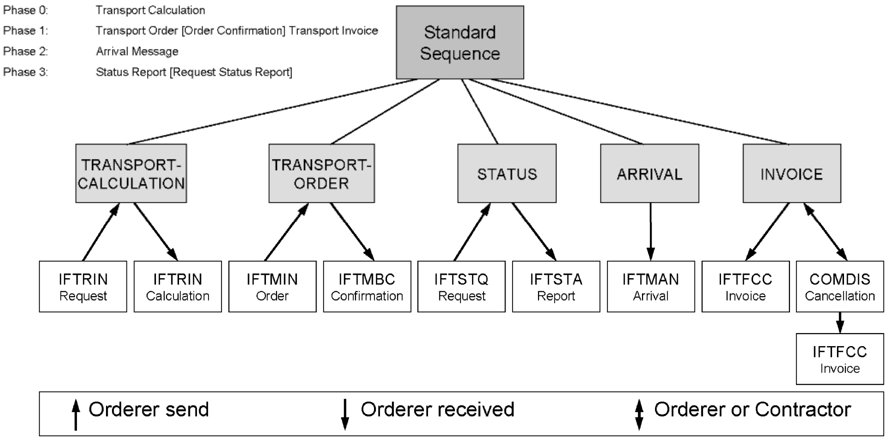


Fig. 7. EDIFACT messages support the complete transport chain (cf. EAN workgroup Switzerland, 1998, www.gs1.ch)

Complex Inbound Supply Chain – An Example

In the last example the goal is to showcase a complete inbound supply chain and what is feasible within this context. The example in question is not fictitious but a real implementation in the context of a global project (Fig. 8). Its technological basis was a web-based solution using a middleware layer and an EDI clearing centre. These controlled the supply chain and the Event Management. Additionally, Track & Trace is available.

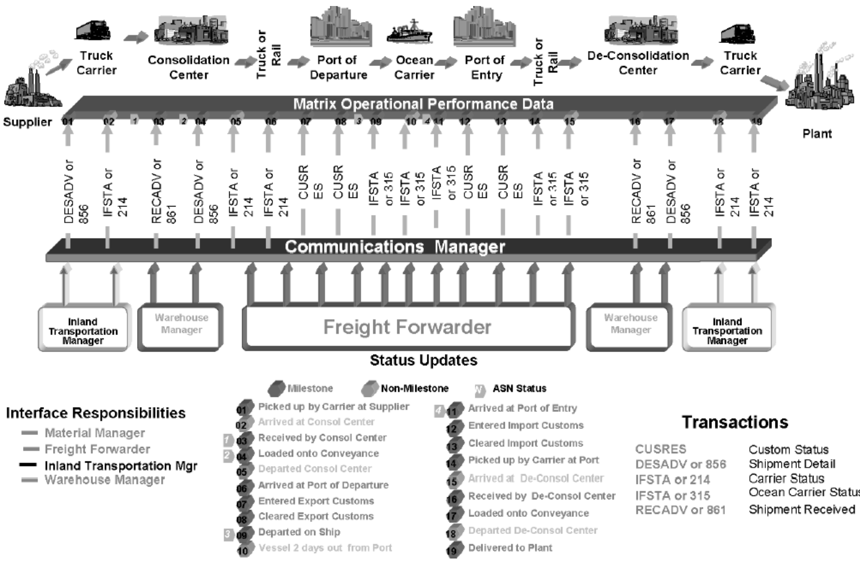


Fig. 8. Example of how interfaces can fully support a complete and complex supply chain

Conclusion

From the examples shown in this chapter it is obvious that it isn't really necessary to bother with creating new interfaces – they already exist and meet most requirements.

What is important is to know how to use them. A requirement for that is the relevant know-how – not only with regard to the interfaces but also with regard to one's own processes.

Pros and Cons of Technical Interfaces

After this demonstration of several positive aspects of IT interfaces, their availability and potential applications, their downsides should not be hidden either.

For instance, the operation of technical solutions does require monitoring. Furthermore, operation and implementation do create costs and in connection with the standardisation there are individual features requiring extra expenditures.

However, in the end, every company will have to make its own cost-benefit analysis.

In order to facilitate decision-making somewhat, possible advantages and disadvantages which may result from using the respective interfaces are detailed below (Table 2):

Table 2. Table of pros and cons regarding the usage of technical interfaces

PROS	CONS
Automated operating processes	Implementation
Avoidance of errors	Operation / monitoring
Synergy effects	Infrastructure
Reducing manual tasks	Change management
Customer requirements	Proprietary versions
More transparent flows & processes	Know-how
Traceability	
Additional Services	

Interfaces Make Event Management Pro-Active

Considering that an operational interface may be the equivalent to an event, especially one aspect in realising it could become a challenge: Acting pro-actively.

As long as human beings are the decisive elements within the chain, there is as risk of things being missed, neglected or overlooked. In this context, the author would like to mention a simple example from daily practice. In the automotive industry the respective terms are the so-called minimum and reportable stock.

This is the warehouse stock connected to the production line feeding from the Supplier Logistics Centre (SLC). As soon as a certain quantity of a particular item is required, a workflow is triggered which generates either a new order for the article or an emergency scenario. This is happening automatically by means of threshold values which have been customised according to the requirements.

To ensure that this will work automatically, technical interfaces are mandatory. Otherwise, the worker in the warehouse would have to regularly and manually check the stock and initiate the corresponding steps, if necessary.

Another example from the transport industry: A truck transporting a time-critical load is involved in an accident or traffic jam. If the driver fails to immediately get in touch with the person responsible and to pass on the relevant information, a production or building stop might be the consequence.

Within the framework of a pro-active Event Management, it is realised that a measuring point has been exceeded and adequate actions will automatically be taken. In this case this might be an email to the dispatcher.

Because of the experience the author gained during his work, he is of the strong opinion that pro-active Event Management is not possible without the respective interfaces.

Conclusion

From the knowledge gained above, the following can be concluded concerning pro-activity and technical interfaces:

- Each operational interface represents an event
- For each event a technical interface can be defined
- For a pro-active controlling of events, technical interfaces are required
- Automatic alerting & monitoring are mandatory
- Improvements of quality and service levels can be generated
- Potentially, resources can be optimised

Do I Really Need Interfaces for SCEM?

The answer is: YES

As has been shown, there are both technical and operational interfaces. Considering this aspect, it is impossible avoid discussing the use of interfaces.
In the end, everybody is part of a delivery chain and in this case an acting member of a supply chain.

So, the more important question to answer is rather: Do I need technical interfaces in order to participate as a partner in a Supply Chain?

Here, the answer is: NO

It is self-evident that you may just as well establish manual processes and that you may act as a partner without technical solutions. However, sooner or later, you might be forced to take IT interfaces into consideration, in case e.g. business has become international or due to customer requirements. In the author's opinion monitoring and Event Management can only be as good as the weakest member of the chain.

Considering all this, the author's recommendation would be to make yourself familiar with the subject and to get as much information as possible in order to use the possibilities for your own benefit.

Participating on Event Management – Use Standards

In case you want to use Event Management, there are in principle two opportunities: In-House or Outsourcing.

In any case, it is necessary to implement and to establish a process within one's own environment. As for the technical solutions, it is possible to either refer to a service provider or to my own expert team.

As mentioned above, there is an adequate technical standard for many processes and operational interfaces. The advantage thereof does, however, disappear with increasing individualization of the original standard. Experience has shown that IT interfaces despite the use of a supposed standard may involve risks concerning time and budget. The reason for this is often to be seen in the implementation of the processes which were defined within the responsible departments.

For example, it was requested by the sales department that customer numbers should contain alphanumeric characters. Consequently, interfaces had to be adapted e.g. to the carriers as in the standard interface only used a numeric field. Furthermore, this had an effect on the transport related label and the barcode printed on it which had to be scanned into the process flow and had to be reported back in terms of sending a status like Proof of Delivery POD.

The IT has a complete toolkit of adequate standards. To ensure its general ability to operate, processes are necessary which use these standards. It is self-evident that bilateral agreements for implementing them remain important.

Closing Words

What I had in mind was to move the main focus away from the general term of 'interface' and towards a more detailed reflection on the subject. Hence, it is very important to me that it should be distinguished between technical and operational interfaces.

I would appreciate it if discussions concerning Supply Chain Event Management were not limited to the IT side. For here there are many aspects which could be used in place. Within the scope of Event Management the focus should be on the operational interfaces and on the use of standards.

Literature

EAN workgroup Switzerland (1998) www.gs1.ch

Proactive Event Management in the Supply Chain of Aircraft Spare Parts

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Introduction

Worldwide airline traffic is expected to nearly double over the next 10 years. In this market, all airlines, whether they are start-ups or national carriers, have to develop their own strategy. Externally, the strategy is to gain new customers, to expand flight routes and to offer a reliable and professional service at a competitive price. Internally, all airlines try to reduce cost and gain flexibility to fit customer needs. Also environmental aspects and airport congestion constraints are getting more and more important which have to be considered (see also Airbus 2007).

The maintenance of aircrafts amounts to about 20 per cent of the total operating cost an airline has. In addition to the cost side, maintenance is responsible for the technical availability, i.e. finally for the revenue. One third of the cost for maintenance is related to the replacement of unserviceable, i.e. broken or defective material. This can be simple screws, coffee machines for customer convenience or wheels which are flat after landing.

But not only the cost for material replacements are important. It is also the flexibility to have spare parts available just at the time they are needed. For example, if material unavailability causes an AOG (aircraft on ground) this could even lead to the cancellation of a fully booked flight. A one-day AOG caused by a possibly inexpensive part costs about 100.000 EUR, not to mention the inconvenience and irritation of the passengers.

Consequently, the availability of spare parts is one absolute precondition for the aircraft availability. One possibility is to store spare parts at each destination the airlines flies to, i.e. at their home bases and at the line stations around the world. The more cost-efficient possibility is to hold them ready for use in one or a few central storage locations in the case of a corresponding request. This, however, requires an efficient management of the different transfer and supply processes and the links and interdependencies between them.

The management of spare parts can be done by the airline itself or by an external service provider who is in charge of the complete material service thus permitting the airline to focus on its core business: keeping the aircrafts flying.

Lufthansa Technik AG

Lufthansa Technik is the world market leader in the maintenance, repair and overhaul (MRO) of commercial aircrafts, their engines and components. With customised programs for MRO, Lufthansa Technik is continuously assuring the reliability and availability of its customer fleets. Subsidiaries of Lufthansa Technik are distributed worldwide. They are linked with each other to support more than 1200 aircrafts and 600 customers. The range of services is tailored to the individual needs of the customers: overhauling of aircrafts after several years of operation, regular maintenance support, emergency services, engine support or special adaptations to VIP customer requirements. Component Services is a separate division within the Lufthansa Technik organisation. Since the late eighties, Lufthansa Technik Component Services has gained a large number of customers outside the Lufthansa family. Today, two third of the business is done with Lufthansa-external customers. In 2006, the company recorded a 3.4 bn EUR revenue.

As the world's largest provider of component services Lufthansa Technik is independent and attends to all well-established aircraft models. With its Total Components Support TCS® and Total Material Operation TMO® Lufthansa Technik is in a position to provide flexibility at comparatively low cost per flight hour and to reduce the complexity of parts supply whereas a single airline operator running the maintenance service on his own has to invest in a large material stock with enormous fix costs apart from the supply management (LHT 2007).

When a small or medium-sized airline customer becomes a member of the Lufthansa Technik components pool, his operating costs can be reduced to a level which is normally reserved only to operators of large fleets. Advanced logistics ensure that everything requested reaches its destination in the shortest possible time wherever in the world the aircraft in need of service may be at that moment. And, for the airline customer, material support means one-stop shopping: instead of having to negotiate with several vendors, just a single service interface remains. Moreover, the customised service package is flexibly tailored to the airline’s specific requirements, e.g. to growing fleet sizes, new destinations, seasonal changes, etc.

Line Replaceable Units and LRU Cycle

Usually, aircraft components are repairable, i.e. reusable units. In most cases, they contain and combine different technologies: special avionic technologies for the navigation systems, mechanics, hydraulics, pneumatics or electronics. The components usually are described as line replaceable units (LRU). LRU are installed in aircrafts once or several times. As against non-reusable spare parts, consumables or expendables, the prices for LRU are high; e. g. an engine control unit can be estimated with 260.000 EUR. Even a coffeemaker costs half the price of a Smart® car. Figure 1 shows a comparison of typical avionic units, on the right side estimated in EUR, on the left side expressed in the multiple of the price of well-known car models. The list reveals that individual units sometimes cost three times the price of an upper-class car.

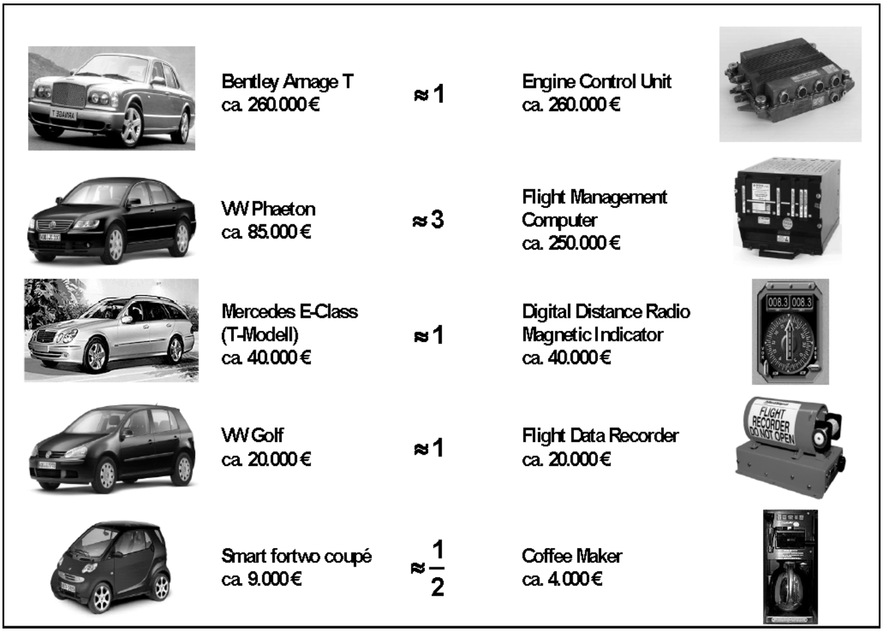

Fig. 1. Prices of electronic components in the aviation industry

The above figure makes clear that aircraft spare parts are partly extremely expensive. For that reason, the aim is to provide a high performance level with only a small number of pieces. Usually, three to four units available are enough to keep the support on a high level with a very long service life. This is what makes decade-long maintenance highly economical.

From the technical point of view, Lufthansa Technik’s customers for aircraft spare parts are primarily the service centres of airlines, and from the commercial point of view, the purchasing departments of airlines being responsible for technical equipment and services. Thus, the performance criteria for Lufthansa Technik as a service provider are, on the one hand, customised and efficient supply concepts, and on the other hand, competitive and transparent prices.

To give an idea of the dimensions, some facts on the Lufthansa Technik’s network for material services:

- More than 90.000 LRU are available in the network of Lufthansa Technik, being worth nearly three quarter of a billion EUR.
- More than 5.200 persons have access to the material request system worldwide.
- Appr. 500 requests per day for LRU have to be fulfilled.
- 400 locations worldwide are provided with material.
- 110 customers are supplied worldwide within the supply network.
- Destinations for requested material can be anywhere in the network.
- Ground support equipment, tools, non-LRU material and qualified staff are required in combination.

When an AOG happens, the time for providing the requested part can be 25 minutes from stock at the location or 4 to 24 hours if requested from somewhere in the world. Generally, a service provider has to fulfil and monitor the main functions and services of the spare parts supply (see Fig. 2). For high-grade (in this case line replaceable) units, these can be roughly subdivided into logistic and service processes towards the customer, the return and MRO of defective units from the customer and the functions necessary to manage and support the supply cycle. According to this, the essential core functions are the servicing and fulfilment of spare parts demands with the customer, the return of unserviceable spare parts, their lead into the MRO process (in-house or external repair), the distribution to pick-up & delivery locations as well as main tasks dealing with repair float quantity calculation, supply management and the management of up-grading programmes (technical modifications and engineering orders) (comp. Schmidt 2006). In this context, support functions are selling of overstocked spare parts, the purchasing of additional service elements (material, repair by subcontractors, logistic services), loan, borrow and sales of spare parts as well as the controlling of operative and economic performance data (see also Ijioui 2007). For this purpose, customer and supplier-specific service agreements and contracts, performance measurement systems and calculation models are set up in parallel.

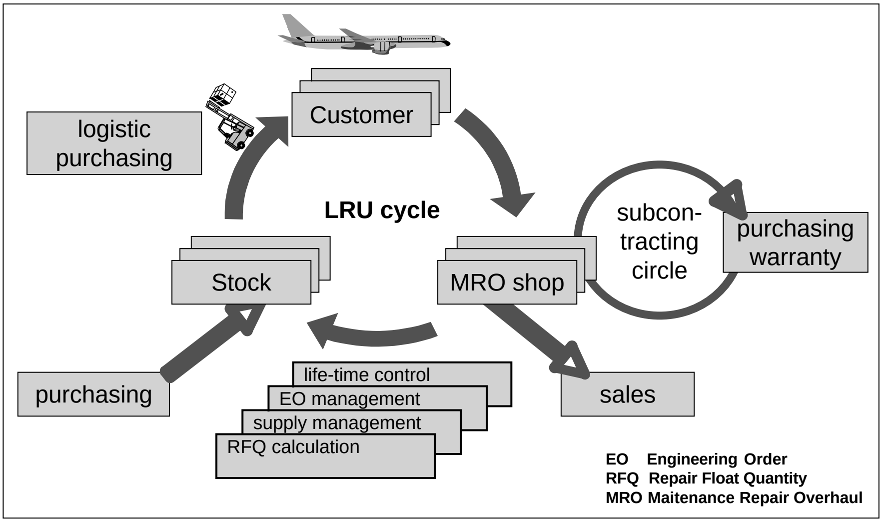

Fig. 2. Component availability – general supply cycle of line replaceable units

Some of the specific requirements on the LRU cycle of airline spare parts are described below in order to show the complexity of reliable service fulfilment in this field:

- **Rules and regulations**: Every process has to be in strict compliance with the requirements of national and international aeronautical authorities (e.g. FAA for USA and EASA for Europe). In addition, airline-specific requirements have to be met. If an event in the supply chain does not satisfy the requirements, the cycle is stopped. Examples:
  - Operation: For every LRU which is mounted as serviceable unit, all operating data are recorded and verified. In the case of defect and dismounting, every step has to be documented (when dismounted, number of flight hours, reason for dismounting, etc.).
  - Receipt of material: All relevant documents have to be available for the receipt, e. g. workshop reports, certificates, data regarding the technical state of the LRU, and the type label has to be readable unequivocally, otherwise it is refused.
  - Shop: Only qualified staff members of accredited repair shops are permitted to take repair measures (EASA Part 145 certified shops). The individual procedures are specified by the manufacturers (CMM: Component Maintenance Manual). The documentation is also subject to given standards.
- **Interchange ability**: Because of a decade-long spare parts supply, modifications owing to changes in the safety regulations or manufacturer specifications, or own modifications are common practice. Consequently, a number of spare parts are interchangeable completely or at least unilaterally. Examples:

  - LHT: Data maintenance regarding interchange ability is taken seriously since a lack of certain interchange abilities leads to parallel stocks with high costs.
  - Customer; If a customer does not receive exactly the requested unit, he asks for the documentation and the explanatory statement for the delivery of an alternative unit (normally documented in the IPC (illustrated parts catalogue)
  - Manufacturer: Manufacturers have to guarantee supply readiness for decades.
- **Maintenance support**: Trouble shooting and localising of an error require flexibility in the parts supply. Examples:
  - Compatibility: Compatibility with other aircraft systems cannot always be guaranteed. This means that from the technical point of view a part/unit exchanged can still produce the same error message,
  - Maintenance: The maintenance tries to reproduce a certain error or to exclude it by means of a unit; i. e. the unit is not defective but supports the narrowing and localisation of an error in the aircraft.

Relating the functions and tasks efficiently with each other in the sense of a service provider requires a corresponding organisational frame. For this, Lufthansa Technik has established a sub-organisation as a self-dependent business unit which is acting with corresponding transparency as to cost and expenses vs. revenues and which also has the freedom of action and decision as regards the market and its further development. The result is a business unit which apart from the inherently marketable product (spare parts supply) provides all functions and services of product supply together with other related units within Lufthansa Technik and operates the system with the necessary entrepreneurial self-image.

Supply Chain Event Management

The supply cycle for LRU can be seen as a specific chain with real processes. It includes a number of processes to fulfil customer requests and to reintegrate unserviceable units to make them available for the next cycle. In this context each individual process is considered as an event (remark: ‘event’ is also used for describing the overhaul of an aircraft after several years of operation). Thus, each event within the supply chain is of vital importance for the spare parts availability. The specific feature of LRU supply chains as against „normal“ production chains is that the end user of a repaired unit is at the same time addressee and trigger for the return of the defective unit to be repaired. Because of this double role and the interactions from the supply cycles another dimension of interdependency is added.

In view of the above mentioned small number of pieces per item number, the movements of an aircraft within the routing network of an airline as well as the safety requirements up to the AOG, the precise planning and control of the supply chain is of high importance (compare Schneider 2007).

Generally, the LRU cycle can be divided into two logistic chains (Fig. 3). The first chain starts with the customer request, typically a stock requisition or request for a specific aircraft, and ends up with the receipt of the spare part. The second chain starts with the customer being in the role of the supplier and ends up in the store (of repaired parts). This is a customer-neutral procedure since there is no customer order stored in this case.

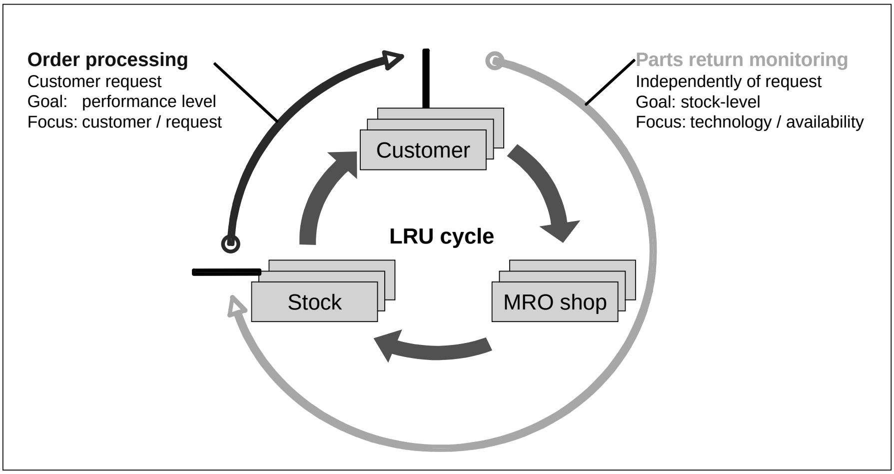

Fig. 3. Supply chain of line replaceable units

The two logistic chains require a corresponding event management: The order control within the LRU cycle is customer-related and aims at delivery on time and the performance level, if necessary. The return control happens anonymously as regards the customer and aims at the material availability ex stock. The order processing consists of three main process steps (see Fig. 4):

- Request examination including contract check, delivery-date and stock-level check
- Satisfaction including availability check and material reservation
- Logistic execution including withdrawal, customs, shipping, delivery and receipt by the customer

The return of unserviceable units also happens in three steps:

- Material return by the customer, starting with the receipt of the unit determined for installation, the exchange / component change and the return until receipt of the unserviceable component at Lufthansa Technik

- Repair process in one or more MRO shops, subcontracting of the repair services and receiving of the unit in the main store of repaired units
- Fulfilment with splitting, i. e. distribution to locations of demand or requests and storage

The return process in praxis allows the customers depending on technology and location between 5 an 50 days. Approximately 400 repair shops are integrated in the network and five main stores worldwide have to be replenished. The different cycle times are causing the splitting of the supply cycle into two separate chains.

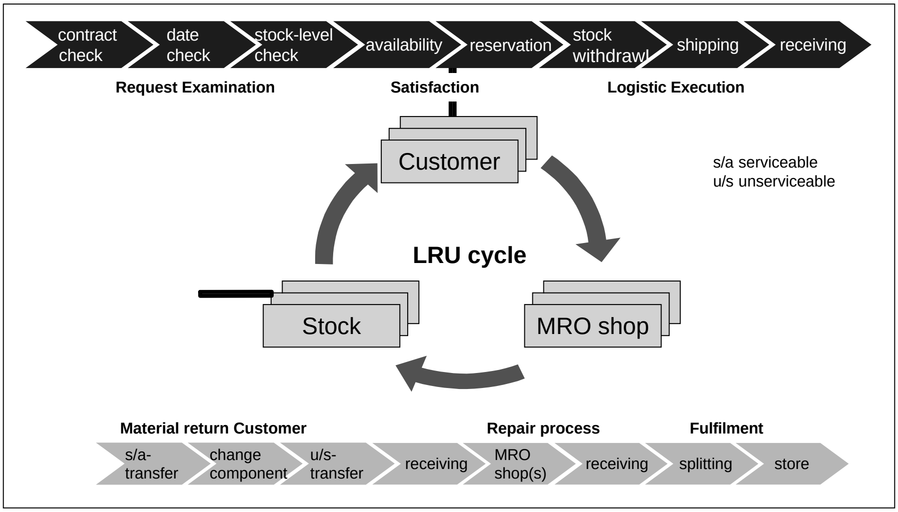

Fig. 4. Events in the supply chain which have to be managed

The process chains shown in figure 4 represent a summary of the main processes. The repair process can take place inside the network of Lufthansa Technik or externally. Here, different providers of MRO services have to be linked together with the worldwide distributed customers in complete logistic networks.

Proactive Event Management with MAterial eXcellence MAX

Lufthansa Technik uses SAP R/3 companywide as business software. Particularly, the business 'Components' required customising of individual SAP modules and the development of additional software since the cycle with serialised spare parts in small numbers typically for a service company requires the reproduction of special business events. The processes and cockpits for the management of individual

events in the LRU supply chain are reproduced in a new software system called MAX (MAterial eXcellence) which will be explained in this chapter followed by a summary of the results and the experiences gained during the introduction of this system. Before starting to design the SCEM system, it was important to determine the roles of the process participants. Based on the roles and responsibilities for the spare parts servicing of customers and the return of unserviceable units, the participants have to be clearly assigned to activities. The principles are as follows:
The responsibility for the performance of the whole system lies with the service provider, i.e. he determines the quantities of spare parts and holds the internal responsibility for the performance level. For the definition of roles exclusively the functions related with the logistic and administrative fulfilment of the supply cycle are considered (e.g. commercial aspects are not taken into account). Each role manages the material flow directly or indirectly; all defined roles have to be occupied to ensure a smooth functioning of the supply chain. One manager can execute different roles. The main roles within the LRU cycle are:

- **Requester**: Requesters communicate the customer’s material request to Lufthansa Technik via fax, e-mail or Lufthansa Technik customer lounge in the internet.
- **Dispatcher**: Dispatchers communicate the customer’s material request within Lufthansa Technik and carry out simple clarifications.
- **Contract manager**: Contract managers are responsible for correct contract data in the case of delivery-commitment checks; they have to care for the administration of additional contract information.
- **Material service**: The material service is responsible for the contractual provision on schedule of the material for the internal or external customer. It can be monitored by the performance level.
- **Bottleneck manager**: Bottleneck managers prevent anticipated shortage situations in time or solve existing bottlenecks. By means of a specific control interface, they overlook all present and future requests and are authorised to allocate “manually” via this interface material to a certain request. They are also authorised in this context to cancel already existing allocations.
- **Return manager**: Return managers are responsible for the material availability. They supervise the return of units on schedule by means of a return cockpit in MAX. If necessary, they accelerate shop and transport orders. Furthermore, they ensure a correct distribution of the inventories within the cycle and monitor the compliance with target and safety inventories in customer and supply stocks.
- **Shop manager**: Shop managers are responsible for the meeting of agreed completion dates for repair orders.
- **Purchase manager**: Purchase managers are responsible for the topicality and the meeting of due dates for the delivery of a unit both in purchasing and in subcontracting a repair. Possible changes of delivery dates have to be entered in the purchase order stored in the SAP system.

- **Booking manager**: Booking managers are responsible for the correct reproduction of the inventories in the SAP and the MAX system.
- **Logistics manager**: Logistics managers ensure the processing of the physical logistics on schedule.

The introduction of a new role concept with clearly defined responsibilities led to a revision and adaptation of the roles in the supply chain of Lufthansa Technik grown over many years. The supply model attending one main customer has thus changed into an open supply network with customers worldwide. Furthermore, an active bottleneck management replaces the hitherto (partly) reactive management of shortages. With this, the fragmented perception of a contract status by different process participants is brought together. One person responsible accompanies a business connection at least on the reporting level. The customer's service claim is regulated in the so-called positive lists added to the contract. In the past, this should have been checked; now, this functionality is an inherent part of the supply process. The responsibility for clarification, however, is incumbent on the material service whereas the contract management has only a support function. Additional information in the contracts can now be processed automatically.

In the past, the responsibilities for the fulfilment were split, based on the IT systems and functions each organisation had. With the allocation of clear responsibilities for a central function, the bottleneck manager, the process is now optimised.

While the bottleneck manager fulfils short-term requests the return manager ensures the stock level in the stores. With an efficient control of the return events future bottlenecks can be avoided. That is the reason, why the roles of the return and the bottleneck manager are in one hand.

For the shop and the purchase manager it is important to keep the due dates for material additions since the material allocation is planned although the receiving has not yet taken place. And with a delayed receiving the risk of bottleneck grows. Furthermore, the purchase manager has to care for material allocation to the right LRU cycle.

The booking manager is responsible for the correct reproduction of the material in the SAP system. As the management and safety regulations require a lot of information (status, documentation), the events can be stopped by any incompliance with administrative restrictions. Therefore, it is up to the booking manager to improve the fulfilment by avoiding process stops owing to the clarification of missing data or information.

Each role has its own cockpit to provide all required information for the fulfilment of the specific role. If for any reason there are discrepancies between planned and actual data about the events, it is visualised and the interpretation is given. This means that all further information and transactions to solve the bottleneck are provided via MAX.

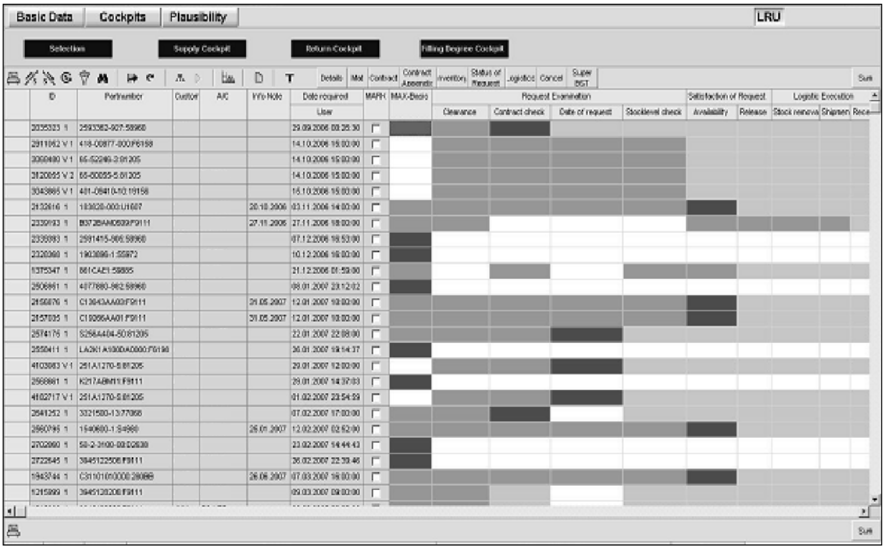

Fig. 5. Screenshot: supply and fulfilment cockpit

The *supply and fulfilment cockpit* (Fig. 5) gives a graphical view of the status per open request within the supply chain and provides detailed information on each request and possible actions to be taken (e.g. bottleneck management). The supply and fulfilment cockpit is split into four parts:

1. Head and task line: There are different buttons available for refreshing a graphic or for the selection of another cockpit.
2. Overview supply chain progress: The overview is split into two parts, one for the processing and the other for the data and information. The part for the direct start of actions uses different colours to visualise the progress in relation of the planned dates.
   a. Part for direct actions: The progress within the supply chain is visualised as follows:
      Green: Event / process took place without any fault / in time
      Red: Process step needs manual processing or was terminated with a fault message
      Grey: Process is in compliance with control profile (but is not yet terminated)
      White: Process is ignored according to control profile
   b. Data and information part: Any relevant information/data regarding the fulfilment of time and quantity requirements are displayed.

3. / 4. Detailed view hint / action: These two views contain additional information for the proactive interaction.

The representation of the individual process chains and the related customer requests permits to monitor the status directly. Based on the time patterns stored in the system it is possible to make active event management decisions. To support the decision making another cockpit mask is available (see Fig. 6).

This mask gives an overview of the major key indicators and the individual events can be analysed in detail in view of the suitable action to be decided. As shown in the example, the changes in the stock level of the selected locations are of particular importance. In this way, the responsible manager disposes of the exact status and the additional information needed to initiate the right action to uphold the required performance in the LRU cycle.

In other words: The different masks and detailed views in the supply and fulfilment cockpit make information gathering easy, and the responsible manager is in a position to decide proactively.

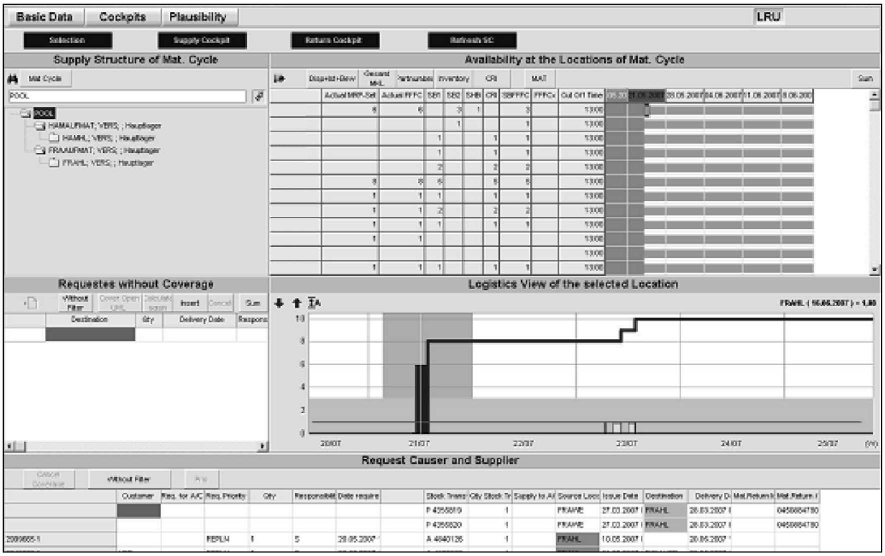

Fig. 6. Screenshot: cockpit for event management in the supply chain

The *parts return monitoring* offers the opportunity of tracing all return events in the LRU cycle beginning with the start returning at the customer location and the component exchange via MRO into the store and allows to easily intervene in the case of process delays, if necessary. Like the supply and fulfilment cockpit, the return cockpit provides a graphic representation of the progress of events as well as detailed information and a catalogue of possible actions.

The return progress is visualised in the same status colours like the supply progress. Processes marked in yellow and red are of particular importance. Yellow means that a timestamp has not reached the planned date but lies still within the tolerance (which is stored in the system). Red means that the timestamp is out of the planned range and has alert status. Particularly, the return monitoring allows strategic actions for a proactive fulfilment. It reduces return times and guarantees high stock levels. Thus, the return monitoring deserves the same attention as the fulfilment of customer requests. Both, the supply and the return management are the key to a high performance in the SCEM for LRU. Apart from the described cockpits there are a number of further cockpits in MAX supporting specific processes. For example, around the exchange of unserviceable LRU against serviceable units can be found revealing information. Compared with the priority of customer requests an in-time return to the MRO is of similar importance. For the maintenance staff responsible, only the availability of serviceable components is deciding. The return of LRU is not in their focus. And the logistics department is interested in consolidating the shipments in order to keep logistics cost low.

All these oppositional goals can be made transparent through MAX, and supply managers are in a position to compare proactively planned with actual events. By means of the described decision support and the detailed information they can anticipate critical events in time.

Implementation of the SCEM Organisation and Software - Benefits and Major Aspects

The introduction of the SCEM consisted of an IT part including implementation of the software MAX and the establishment of clear organisational structures with responsibilities and roles within the supply process. Another point is the change management, which has an important role. Especially the managers, who fulfilled before the implementation different roles were active integrated and informed about the progress of the MAX project. Their input and feedback was one key issue of the implementation.

The project duration from the decision to the concept and finally the realization was three years. With a team of up to 15 people, the project management had to cope with a large number of topics and to solve all kind of questions. Both hardware and software had to be sustainable to fulfil the future performance and data requirements. The organisational changes had to be prepared, agreed and coordinated with the works councils. Staff members had to be qualified and trained as for the new tasks. The cooperation between the IT department and the component department during the implementation generated synergies which led to the definition of realistic goals, the usability of the systems and the unanimous goal of increasing the performance.

As usual, the project plan was divided into several phases. The analysis started with a projection of results based on the situation. Particularly, the open structure to adapt the service to the customer requirements and to launch new service products to the market was in mind. Based on the project rough and fine planning the structure of the concept phase was designed. Based on the concepts the implementation of organisational changes and IT development and programming took place. After the implementation, training sections and a concept for the assistance during the initial transition phase and the future support were prepared. The staggered ramp-up for uncritical and safe operation under full load was the final step in the implementation process. The following highlights and interesting aspects arising during the implementation of MAX LRU have to be marked as very important:

- Extremely complex interdependencies between different IT systems: The design of the data model to establish an easy "non-redundant" storage of information was an important issue in the IT part.
- Experts from the responsible operative departments were extremely important to verify the quality of results. Based on their experience, an efficient organisation and smooth processes were designed and implemented.
- Communication of the project status and marketing on all hierarchy levels took place. Especially, the open communication created confidence so that no hidden "road blocker" could come up.
- "Project quality first!" was propagated by the review board of the project. This meant for the project managers that there was flexibility for adjust the plan if sudden challenges occurred or better solutions seemed to be possible.
- Numerous mile stones and intermediate steps were planned. Especially, the splitting of the project contents into phases in order to reduce the complexity of the challenging tasks were one major effect on the way to implement the SCEM.

The following figure 7 gives a line-up of the initial starting situation for Lufthansa Technik and its major challenges in regard to the SCEM aimed at. In addition to the market requirements including the launch of new products and the change of customer needs, the support to accomplish the goals were not in compliance.

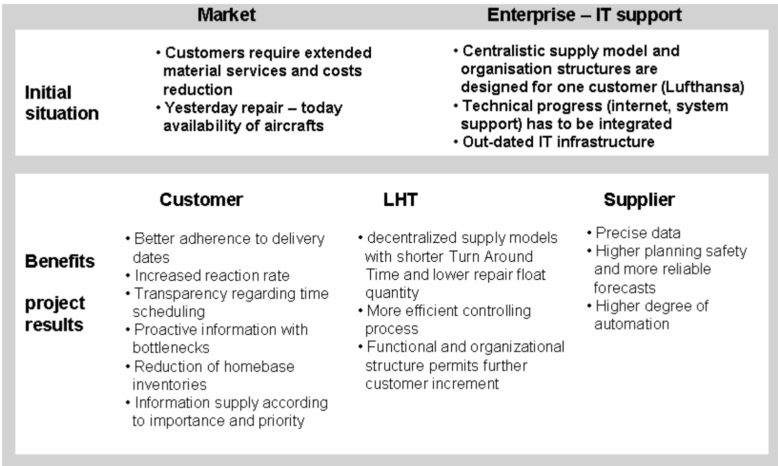

Fig. 7. Starting situation and benefits of the implementation

In view of the initial situation, the project results were tremendous. The benefits can be differentiated according to customer, Lufthansa Technik and supplier. The customers mainly benefit from more reliable services and improved information quality. For Lufthansa Technik, the main focus is on the fulfilment of customer requests while keeping the repair float quantity small. The suppliers are informed more early and can also improve the efficiency of their own SCEM. The goals of a proactive management of events in the supply chain are summarised in figure 8. In addition to IT support, proactive event management needs the parts availability and efficient event management. The organisation has to be implemented with its specific processes and the strategic goals to meet the operative and strategic results. All event management activities have to be seen in regard to the safety requirements for an aircraft. The classification into Go, NoGo and GoIf items essentially influences the decisions. For example a navigation computer is a NoGo item, a thrust reverser can be a GoIf item in case all runways have long lengths, a coffee machine is only important if you have the passenger convenience in mind.

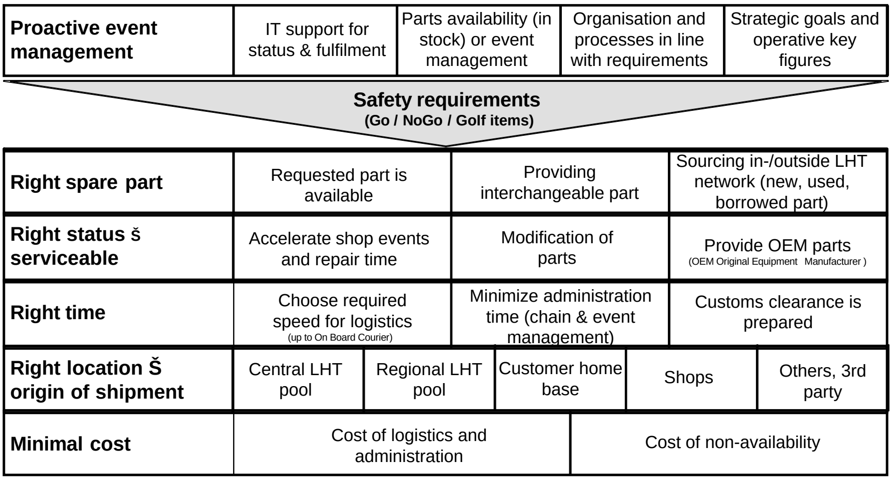

Fig. 8. Goals of supply chain event management and spectrum of actions and possible solutions

Following the “R” rules for logistics targets, Lufthansa Technik has different opportunities to reach the goals (compare Wildemann 2004). With the shipping of the right spare part to the customer, the right status (means serviceable) is in focus.

The right time is influenced by logistics issues and administration / processing times. The right location as the origin of the shipment is especially important in the global network. Finally, the question of cost minimisation is nearly of equal importance as the other topics. The costs of non-availability also include the inconvenience for the airline passengers. The safety requirements by airlines and national authorities, however, are at any time of higher priority than any of the SCEM criteria.

Timeline of Activities Relating to the Introduction of SCEM

The following figure is to give an impression of the time dimension and the main activities in connection with the introduction of SCEM with Lufthansa Technik.

The main topic in 2006 was the implementation of the new request management system which included the MAX system. Like all activities around material management, the internet applications including the customer lounge will then be improved as well in 2007. Particularly, Lufthansa Technik Logistic has strategic goals focusing on the new opportunities offered by the open IT world, the integration with other logistics providers and the global business by controlling the end-to-end logistic processes. For that reason, the Lufthansa staff has to be continuously trained and qualified. The implementation of further regional material pools in compliance with the customer fleets will take place over the next years. With the implementation of additional regional pools Lufthansa Technik's supply chain can still be extremely shortened and is one major step to guarantee its high performance level in the long run.

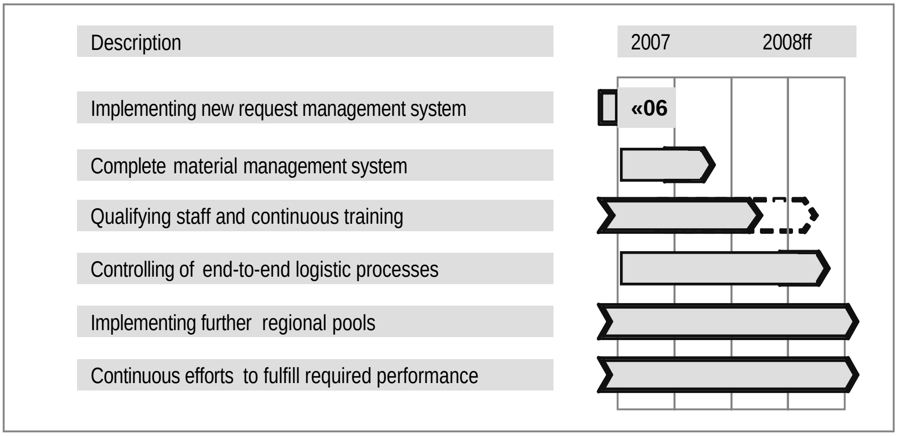

Fig. 9. Major activities and the timeline of projects in regard to material management and SCEM

Summary

The supply chain of aircraft spare parts has special features as regards complexity and the consequences in the case of non-performance. However, with an integrated stock and supply chain management, the risk can be reduced. The condition is that the supply chain management takes any of the related processes seriously. Lufthansa Technik improves its services according to three important aspects:

Operative flexibility

- Key indicators and figures per customer are monitored.
- Events which are critical for success have special attention.
- Alternative sourcing with strategic partnerships are implemented.
- If solutions do not fit customer needs, suggestions/best possible solutions have to be provided in any case to the customer (AOG).

IT Support and Processes

- Management tools are implemented with levels of escalation.
- Interfaces to logistics partners, customers and suppliers are continuously optimized.
- High attention is put on data quality and accuracy of information.

Strategic goals

- Regional hubs and pool locations will continuously be established to provide shorter response times, transport and local presence.
- Stock levels are continuously adjusted based on criticality, invest and processing effort.
- New service products (e.g. TMO) with customised process design and IT integration are available.

The implementation of a supply chain event management is always a large step towards efficiency and fulfilment of customer needs. At the same time, the development of internal structures and tools to provide better services is not always easy to realise. The implementation of software solutions goes hand in hand with process and organisational developments. The challenge is to provide a part just when an AOG happens and maintenance solutions need to have the flexibility of a material management provider in the back.

For Lufthansa Technik, the prime topic is:
Safety first!

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Supply Chain Event Management: Managing Risk by Creating Visibility

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Introduction

Today's business world is defined by complex business relationships. Some companies outsource their business activities to such an extent that they only own the brand name. Nonetheless, controlling the business and having overall transparency is key for them to ensure their customers' satisfaction. This situation is intensified by faster product development cycles and shorter product life cycles. Customers and consumers also demand higher service levels and high availability of products. The growth of globalization, supplier dependency, and variability of demand has led to an increasing vulnerability of supply chain networks when disruptions occur. The foundation of adaptiveness lies within operating the supply chain through planning and execution, sensing deviations, and responding to them. To identify risks, develop efficient response strategies, and monitor the actual processes, a disciplined approach is necessary.

This is the realm in which supply chain event management (SCEM) is at its best. It allows companies to manage by exception rather than monitoring processes that are running smoothly, to be able to recognize and react to unplanned events in the supply chain, to provide a single point of access for collaborative processes, and finally to measure business partners' performance. In addition, managing supply chain risks requires taking a specific perspective on the supply chain and the involved business partners, locations, and dependencies on different levels in the value chain.

To support this business approach and make strategies become reality, a variety of tools and solutions can be brought into play to enable effective supply chain risk management.

With SAP Event Management (SAP EM), an application within the SAP Supply Chain Management (SAP SCM)™ application, SAP supports SCEM. This article shows how SAP Event Management increases visibility into business processes and therefore enables supply chain risks to be managed.

Managing Risk in Supply Chain Management

The globalization of supply chains has resulted in an increase in the number of business activities spanning the entire globe. Offshoring and nearshoring business activities cover the entire range of the value chain. The result: Efficiency gains and cost reduction as well as increased collaboration with and dependency on partners, and longer transportation times. Globalization provides opportunities at every step along the value chain, from product development; sourcing, manufacturing, sales and service to disposal (see Fig. 1). However, globalization also brings with it increased risks: "As supply chains are becoming more brittle and the world is growing uncertain, concerns are increasing about low-probability/high-impact events that can bring about major earning shortfalls or even unplanned exits from business." (Sheffi 2005, p. 13) The growth of globalization has made supply chains more vulnerable. Small disruptions can have big effects, as a very well-known example shows: A minor fire in a Philips chip factory in New Mexico caused major effects for its customers, Nokia and Ericsson (see Sheffi 2005, p. 3). While Nokia proactively dealt with the incident, Ericsson was hit hard by the consequences of the fire. The major difference was how the actual disruption was solved through quick responses which were key to responding to risks successfully. Simchi-Levi 2007 defines five methods to deal with supply chain risks: Speed, flexibility, redundancy, risk sharing, and risk pooling.

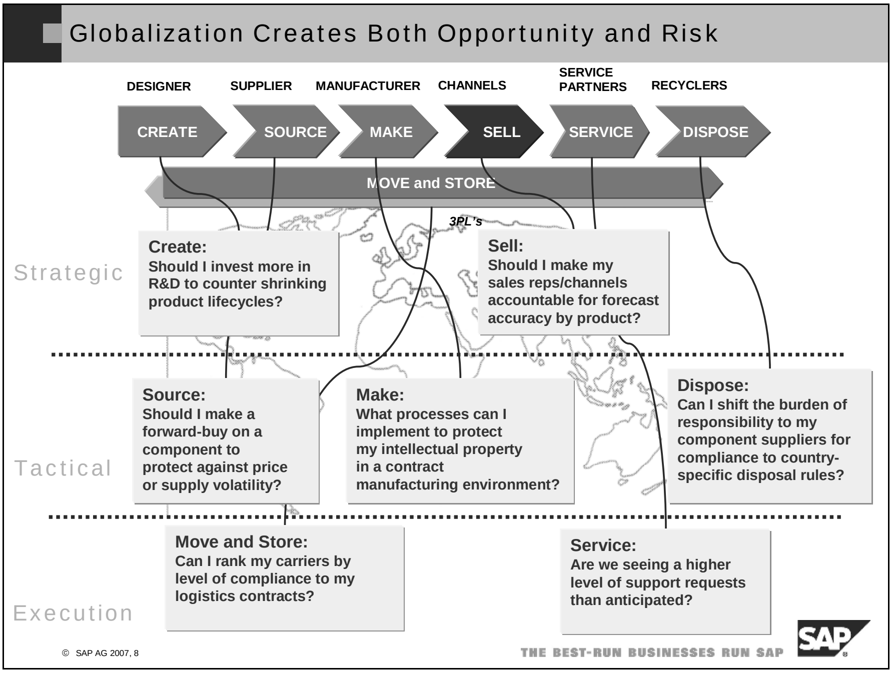

Fig. 1. Risk management and globalization

What does this mean when addressing risks in supply chain management? It's all about getting risk management embedded into the business behavior rather than relying on a single tool. Managing risks requires a disciplined approach that is translated into strategic, tactical, and execution-oriented solutions in order to mitigate, transfer, or simply avoid the effects of disruptions resulting from supply chain risks.

Strategic, Tactical, and Execution

When incorporating risk awareness into supply chain management, risk management can be addressed on various levels. Strategically, the mitigation of risks has an influence on business continuity planning, the setup of the entire network through network design, and postponement strategies (see Fig. 2).

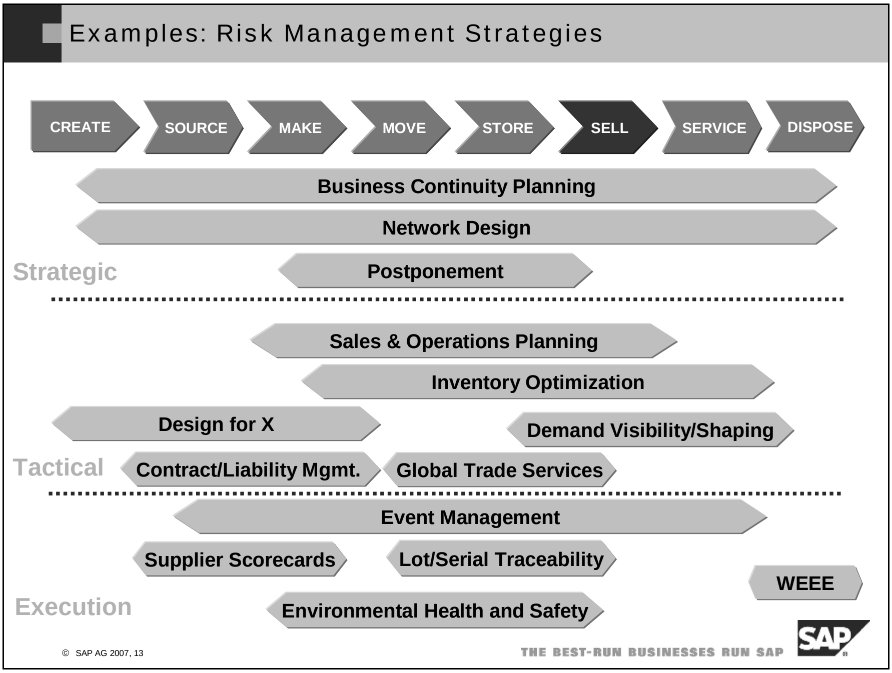

Fig. 2. Risk management strategies

Supply chain visibility is the key enabler to manage risks close to the actual execution. Visibility enables the immediate identification of critical situations and an optimal response to them. Three fundamental aspects of visibility provide a full perspective on the supply chain:

- **Process visibility** enables milestone monitoring supported by the capture of actual events. It is connected to alerting and event resolution, and serves as a basis for collaboration and coordination with partners.
- **Product and asset visibility** ensures the compliance and responsibility for goods delivered from the manufacturer to the consumer (for example, food safety or Product Tracking and Authentication (PTA)). The tracking and tracing of capital assets through the entire life cycle provides visibility into the location or status of high-value or critical products and assets such as returnable transport items, technical equipment, machinery, tooling, and so on. In addition, product stocks and inventory locations are visible and can be identified.
- **Performance visibility** enables the management of supply chain performance with key performance indicators (selected metrics) to close the feedback loop between target and actual values. The visibility into performance provides easy access to analytical data and enables the combination of analytical insights together with transactions and activities.

All different aspects are involved in managing events and sharing them with business partners or across department silos. In this realm, supply chain event management serves as a basis for creating visibility and managing risks (e.g. Fig. 3).

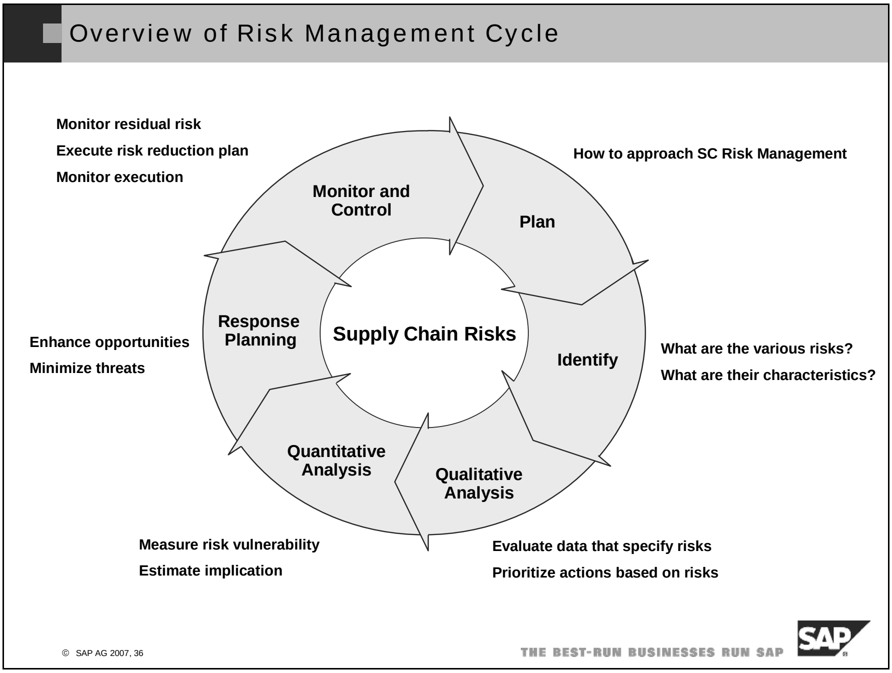

Fig. 3. Framework for managing risks

In order to create a comprehensive perspective on risks, a closed-loop process supports the definition and adjustment of a supply chain risk strategy. This process is represented by a framework of processes:

Plan Risk Management

Definition of the approach to supply chain risk management. Create a supply chain risk management plan that defines:

- Methodology — approach, tools, and data sources used
- Roles and responsibilities — lead, support, and risk management team for each type of action in the plan
- Budget
- Scoring and interpretation — should be determined according to the type of qualitative and quantitative risk analysis to be performed
- Thresholds — the threshold criteria for risks that will be acted upon, by whom, and in what manner
- Reporting format — content and format of risk response plan
- Tracking — document how all facets of risks will be recorded for future reference and how risks are to be audited

Identify Risks

Factors that influence risk management and supply chain management as a whole cover strategic, tactical, and execution-oriented areas. Addressing risks in the supply chain therefore requires the identification of risk events and vulnerabilities. Process steps include:

- Create a risk management plan that defines methodology (approach, tools, and data sources used) as well as roles and responsibilities
- Define scoring and interpretation of events (qualitative and quantitative risk analysis to be performed)
- Set threshold criteria for risks that will be acted upon
- Define reporting format (content and format)
- List supply chain risks and define area (for example, in transportation, internal, supply, or demand)
- Classify supply chain risks into *known unknown* based on historical data and experiences or *unknown unknown* (see also Simchi-Levi 2007, P. 6)

Measure Risks: Qualitative and Quantitative Analysis

Following the qualification of risks, risk events and their occurrence need to be measured. To enable measurements, the service providers' information sources are used to assign the probability of the occurrence. Impact levels (subjective or objective) are assigned. This includes the identification of KPIs that measure the impact (including a financial impact). To provide visibility into the entire network, control systems are established as sensory networks. Process steps include:

- Collect historical data from experience (*known unknown*) and with known probability distribution
- Identify databases or services for probabilities of catastrophic natural events (earthquakes, storms, and so on) by geographical location (*unknown unknown*)
- Use simulation tools to enable scenario planning, and enable decision support
- Gather data about business partners
- Collect event data via supply chain event management

Manage Risks: Response Planning and Monitoring

To successfully manage risks and the resulting effects, responses must be identified. This may cover risk mitigation plans, hedging and trading mechanisms as well as documenting risks and responses. The main question to be answered concerns avoidance and recovery strategies. Process steps include:

- Define risk impact by indicating location and/or process step of disruption
- Develop process and scenario alternatives
- Define risk mitigation strategy
- Evaluate costs of mitigation strategy
- Provide integrated and interactive display of most critical risks
- Translate mitigation strategy into actions

The Need for Network-Wide Visibility

For companies to be successful in the modern, networked, global business environment, they need to be faster, more agile, and more productive than ever before. In order to respond to constant changes, the demands of increasingly savvy customers, and fiduciary responsibilities to shareholders, many companies are focusing on core competencies and partnering to achieve success. Partnerships and business communities are formed to create win-win situations in which collaboration, outsourcing, and information sharing are critical success factors. The pressure to reduce costs remains unrelenting, but cost reduction is not enough. Innovation and growth are the watchwords of today's economy – and of the economy of tomorrow, as well. The velocity of change in customer needs and trends makes innovation a key competitive differentiator for achieving profitable growth. The best-performing companies integrate innovation into their core business processes and focus on time to volume and time to market. These factors result in a pressing need to reach beyond supply-driven efficiency. The preferred business model is fast becoming a pull-driven or demand-driven environment, and the ultimate source of demand is the customer. Companies must now move to balance their supply chains based on these new push and pull dynamics. In order to anticipate customer requirements and better respond to their demands, companies must bring high-quality, value-added products to market faster than the competition.

To achieve better visibility up and down the supply chain and to use it productively, companies must close the loop between planning, execution, and evaluation. They must integrate the ability to adjust plans on the fly based on feedback and information received in real time. To accomplish this, companies need to implement integrated software that supports major business processes such as monitoring supply chain events, notifying the right person in case of a delay or critical event, simulating activities, controlling processes, and measuring supply chain activities to adapt business operations and make them more effective and efficient.

How SAP Customers Use SCEM Today

What exactly is the challenge? In today's world, it is about managing information in heterogeneous systems and disparate silos separated by departmental, geographic, and even organizational boundaries; and still being able to detect, evaluate, and solve problems in real time and grow a community of collaborative, cooperative business partners.

Depending on the industry or supply chain model, the mode of usage of SCEM varies. Consumer product companies with complex domestic networks, for example, tend to focus on visibility and control of their finished goods networks (including third party), while high tech, retailers, and soft goods companies with significant offshore supply bases put effort into visibility to purchase orders and shipments across these long supply chains.

Industries that have already begun to splinter into multiple best-of-breed businesses include automotive and high tech, which began 15 years ago, utilities and telecommunications in the 1990s, and financial services more recently. As this continues, firms increasingly comprise interdependent units supported by service-level agreements with internal and outside providers. In such an environment, effectively empowering people with the right information, at the right time, and in the right context, is critical.

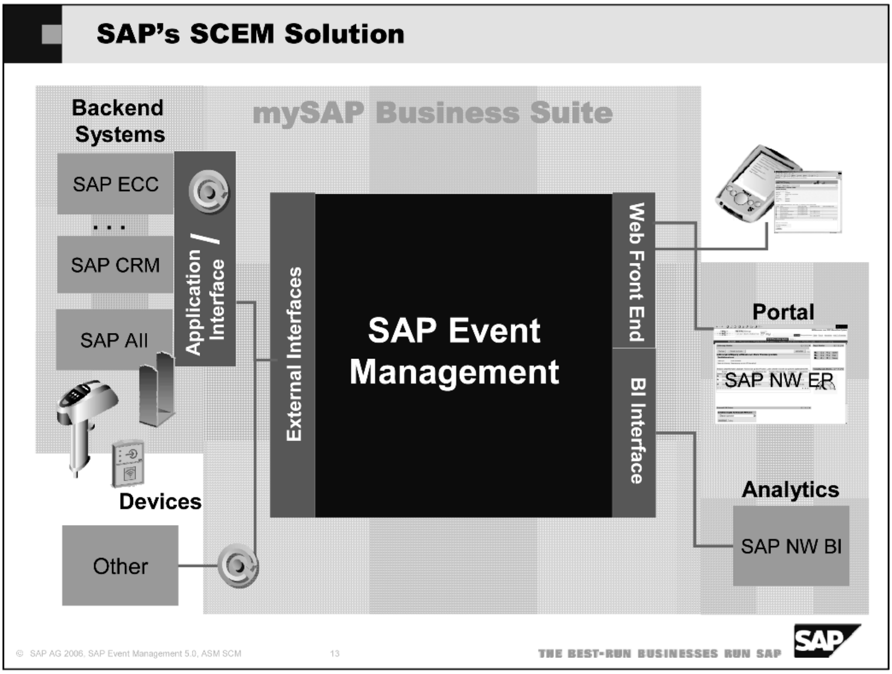

Fig. 4. SAP's SCEM solution

SAP EM provides the functionality that is needed for a sophisticated SCEM solution (see Fig. 4). This is enriched by analytical capabilities residing in SAP NetWeaver™ Business Intelligence and simulation/control capabilities within different application systems. SAP EM is widely used within different industries, manufacturing as well as service-oriented ones.

Evaluating performance visibility takes place after the fact, which means that usually after a process has finished or reached a specific status, specific key performance indicators are determined and can be used as a basis for latter decisions and process adjustments.

How It Works in Detail

In a customer implementation, a business blueprint is created to lay out which processes are to be monitored, and which business partners and objects are involved. There is probably no one project that is exactly like another. This means that the solution has to be very flexible. That said, customers usually look at similar processes. That's why SAP provides not only SCEM functionality, but also predefined configuration, that is, visibility processes that are shipped with the relevant systems.

Based on this, the system setup can be finalized, including integration with third-party applications. When integrating with an SAP application system, an SAP EM application interface is available that allows the configuring of the data exchange rather than programming it. When integrating with third-party applications, different options are available, including sending data via EDI, or sending XML messages.

Furthermore, a Web user interface (see Fig. 5) with a comprehensive role, authorization, and filter concept is available that allows the different parties involved to monitor the exact parts of the process that are relevant to them, and to also send events. In a make-to-order process, for example, the sales executive is allowed to see all the detailed steps of his or her customer's fulfillment processes including manufacturing, whereas the customer is granted access to only a subset of information related to his or her sales order(s). In contrast, a carrier usually transports different deliveries meant for different customers, so he or she should be able to see the transportation-related process steps for his or her specific shipment only.

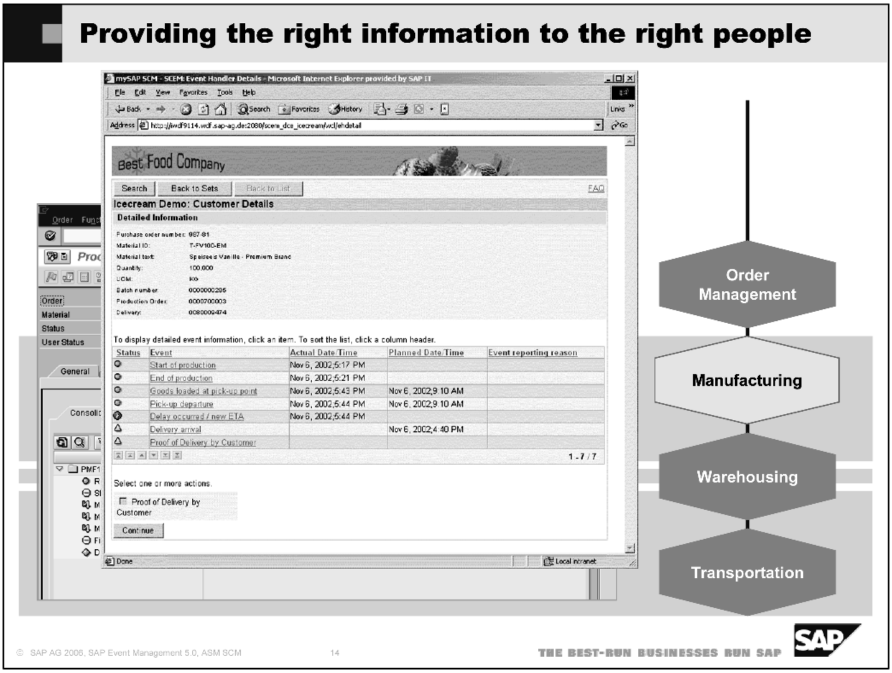

Fig. 5. SAP EM Web Interface

Each relevant process is represented by an object in the SAP EM system, complete with identifiers and attributes that are used to monitor and control the process, and with the milestones that are of relevance to the process.

The milestones are either adopted from an application system or calculated based on given criteria. Different milestones can be grouped and can occur multiple times, so that you can easily model a transportation chain via different distribution centers, for example. When an event then is posted, it can be categorized (see Fig. 6):

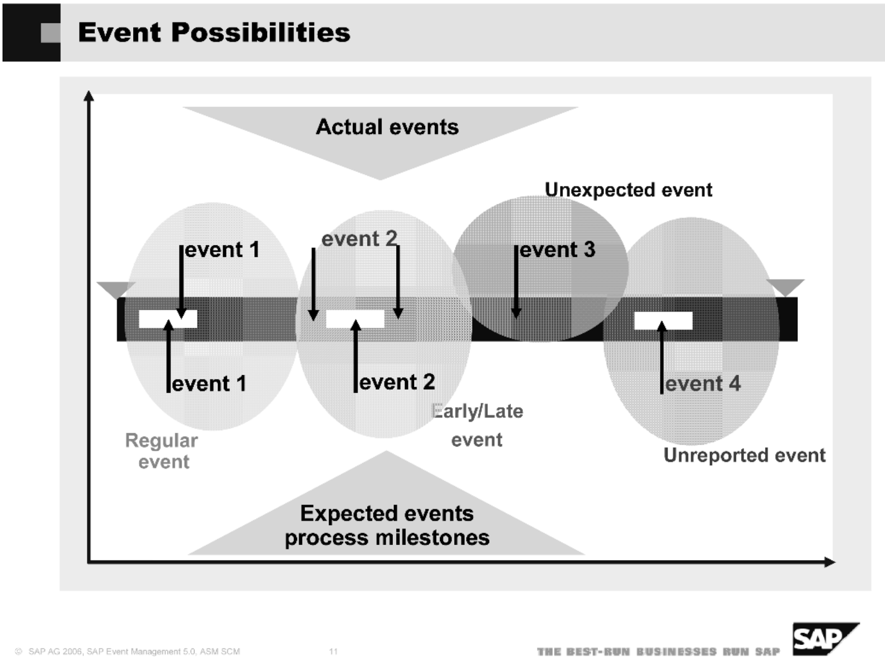

Fig. 6. Event categories

- The event is related to a milestone and it occurred within the given tolerances – this is a regular event.
- The event is related to a milestone, but it occurred outside the given tolerance – this is either an early event or a late event.
- The event is not related to a predefined milestone – this means that it is an unexpected event, in other words, something that needs to be taken into account, but is not planned, because you usually do not want it to occur during the process (for example, a delay in transportation).
- A specific milestone is not reported although the due date has been reached – this means that the respective event is overdue.

The event is saved to the database. This includes not only the event date and time, but also the time stamp when the event message was sent, which can be used to measure the business partner's reporting compliance, for example. Overdue events are also recognized.

A rule engine determines what needs to happen in this specific case. Follow-up activities can be triggered in SAP EM or in the application system, a status can be set, data can be adjusted, and, in the case of an exceptional situation, the respective stakeholders can be notified via an alert.

Responding to Disruptions: Create Visibility and Collaborate

A major German chemical manufacturer decided to implement the SAP Event Management application (see also Success Story 2005) to monitor ocean-freight logistics from receipt of initial orders through to delivery of products to the customer, achieving the transparency it needs. The implementation went live after a six-month pilot project.

"The most impressive evidence of the value of SAP Event Management came less than a month after go-live," a senior executive says. "In quick succession, two major hurricanes, Katrina and Rita, caused havoc at two of our major ports of entry into the United States. Despite the scale and sudden nature of these disasters, we were able to easily cope with any disruption. We had instant visibility of which shipments were in each port and nearby." Shipments were rerouted to safe harbors dynamically as details of the hurricanes became clear; in some cases they were rerouted several times as the situation changed. "SAP Event Management helped us avoid damage to shipments worth millions of dollars. Our customers were impressed that throughout these natural disasters, we continued to maintain a high level of service and kept them fully informed of developments at every stage."

SAP Event Management was put to the test just one month after going live during the two major hurricanes that recently hit the U.S. coast: Rita and Katrina. The Port of New Orleans and adjacent storage terminals were directly in the path of Hurricane Katrina, and the Port of Houston and a key plant were directly in the path of Hurricane Rita. "We knew which consignments were still in port, which ones were in transit, and which ones had already reached their destination port in Houston or New Orleans. We could therefore take the necessary steps to ensure that our customers suffered as little as possible," explains a European project team member. This information helped the company assess risk and prioritize actions, to ensure the safety of personnel and to minimize damage to shipments. Considerations such as product vulnerability and security, business priorities, customs requirements, and mode of transport constraints were incorporated into the decision-making process. Only 24 hours after the first hurricane, Katrina, had hit New Orleans, staff members had a complete listing of all containers that had been received by the Port of New Orleans prior to the hurricane. Shipments previously destined for New Orleans were rerouted to Houston. Shortly after Hurricane Katrina had passed, Hurricane Rita threatened Houston, posing potential danger to the many shipments that had been diverted to Houston from New Orleans and intensifying congestion at the Houston port. Staff members were once again able to assess the situation quickly and prioritize actions accordingly. Within 48 hours after Hurricane Rita had hit, they diverted shipments to safe harbors and planned alternative sourcing strategies.

In addition, by combining information from SAP Event Management with dangerous goods and hazardous-material information maintained in other SAP solutions, they had reports that supported informed risk assessment and decision making about product vulnerability. The company's fast response during Hurricanes Katrina and Rita was impressive. Houston and New Orleans are two of the main ports of entry into the United States. The newly installed solution ensured ongoing business to customers and prevented damage to shipments worth millions of dollars. The company was able to continue providing excellent customer service despite the scale of those natural catastrophes.

The Role of Real-World Awareness

Real-world awareness allows you to react to something that happens in the real world in a timely manner, which means to sense the status and condition of physical objects and be able to take appropriate measures based on this. This includes sensor data, telematics as well as technologies that allow the managing and controlling of single items.

RFID in Logistics

With RFID technology, companies can facilitate data capture through automation and item-level identification using standardized processes to attain enhanced visibility. The ultimate goal is to close the loop between action and automated information. This means making access easy and providing prompts and guidance to help the user take appropriate action while the system provides feedback and forecasts along the way. By enabling the identification of single items in the network, RFID is helping companies improve visibility into their inventory data and increase accuracy up and down the extended supply chain network. Companies can use RFID to make inventory data more transparent and accurate, allowing them to speed up the delivery process, respond more quickly to customer demand, and reduce overall costs. The technology can be used to track individual items or pallets throughout the supply chain: across the factory floor, from loading dock to stack in the warehouse, and onto retailers' shelves. But RFID is not a silver bullet, as there are significant challenges to integrating the technology into existing systems.

RFID is seen as an enhancement to identification technologies, and it allows much more visibility into inventory status and event management than other methods, with great potential to truly automate data collection. Bar code technology, for example, requires repeated manual reading to track inventory, while RFID allows for passive data tracking at any point. And RFID identification tags offer the potential to carry additional code, allowing for much more information gathering. This adds to the challenge, as use of RFID technology generates huge amounts of data to handle.

Given the amount of data that RFID can generate, it is important for companies to be able to fully incorporate RFID into their supply chain networks. Complete process support is needed to capture and handle RFID data, streamline and automate supply chain processes with RFID, and integrate RFID information into enterprise systems.

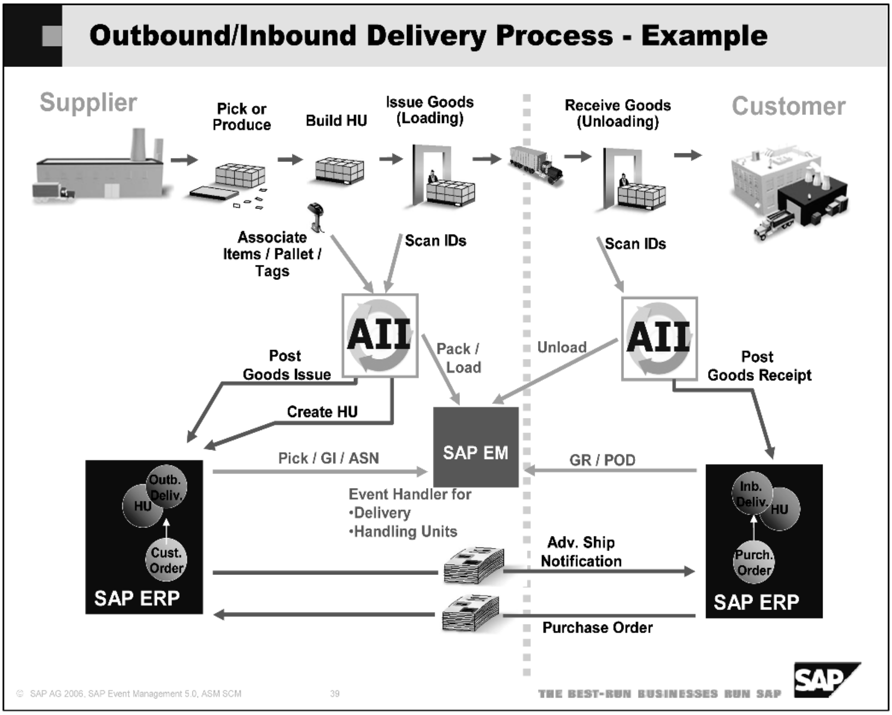

Fig. 7. Delivery visibility

RFID also moves companies closer to truly real-time information, improving on the capabilities of bar code technology with automated identification. While supply chains are now much more adaptive through new event management solutions, as data still comes from electronic data interchange feeds or from business partners' systems, these solutions fall short of the potential of RFID and would more accurately be described as almost real time.

When RFID tags are attached to products, boxes, and pallets, the items can be followed automatically as they move, providing an up-to-date and accurate view of inventory – and greatly enhancing the ability to track and trace goods along the supply chain (see Fig. 7 for an example). The end result is reduced costs, faster response to changing customer demand, and an improved ability to have the right product in the right place at the right time. If RFID technology is more fully and comprehensively integrated in a company's enterprise system, then true real-time information and greatly improved visibility into the supply chain is possible.

Geo Location

Only knowing that something is in-transit is often not good enough, especially in cases where goods are exchanged in a collaborative business environment. The following are some examples:

A company sells gas products. To be able to transport the gas, it is filled into cylinders. Those cylinders are owned by the company, and they represent a significant value. To be able to fulfill their customer orders, the company always has to ensure that enough cylinders are available. This does not work out very well; they actually found out that they suffer 20% order loss due to cylinder shortage, although they already have a comprehensive set of enterprise applications in place. The one missing piece is the information about the current locations of their cylinders. So applying a device to their cylinders that allows the sending of a regular position update, linking this into SAP EM, and then tying findings out of that into the different applications would provide a huge benefit to them and eventually allow them to significantly reduce their order losses.

For an OEM in the automotive industry, it is key to know whether a sea shipment of critical parts is on-time, or possibly delayed. Based on this information, a supply chain coordinator may need to take immediate corrective actions to prevent parts shortage in production – without relying on the shipper to inform him or her about this situation in a timely way.

A life sciences manufacturer has equipped all trucks carrying goods worth more than Euro 1.0 million with tracking devices, since some of their trucks had been stolen in the past. For similar reasons, but going one step further, consumer products company in Latin America tracks their fleet with the help of an SAP Event Management system (see Fig. 8) and is thus able to take corrective actions in the right business context.

An oil company, on the other hand, needs a solution that provides up-to-date information about the ships underway to better be able to fulfill the replenishment demand at their refineries. This is also relevant to logistics service providers who are bound to service level agreements to ensure their customers' satisfaction.

Sensor Data

In the consumer and life sciences industries, goods have to be transported that are often perishable, which means that they need to be cooled and that a certain transportation duration should not be exceeded. Specific trucks are available that allow cold chain transports – but still, malfunctions or a combination of specific conditions may lead to spoilage of the goods. This can often only be detected with the help of an optical quality inspection at goods receipt, and not only the retailer, but also both the carrier and the manufacturer have a strong interest in ensuring product quality up to the end consumer. Applying a temperature sensor to the truck or the transportation container enables, in combination with geo tracking, for example, the timely notification of problems before they arise and provides more time for actually resolving the problem.

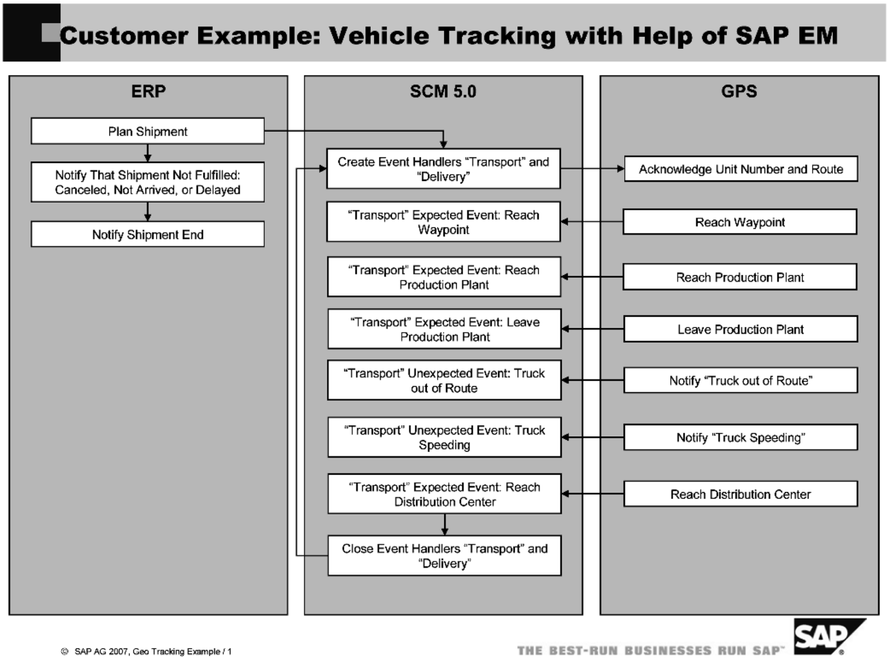

Fig. 8. Vehicle tracking

Voice Integration

In order to retrieve the data necessary to provide transparency for processes that, for example, are not solely controlled within a manufacturing site, companies must provide adequate tools for data collection and retrieval. If a truck driver needs to report his status, he usually does not have an online connection to the application available to send back the relevant information. Furthermore, a customer may want to check the status of his or her sales order without sitting in front of the PC.

Providing a tool for this is a prerequisite for data quality, as the timely posting of relevant information is key for being able to react to exceptional situations. Voice-enabled event message sending, as it is supported by SAP, is a great means to get to actionable information that, for example, eventually helps to measure the partner's performance.

Looking Forward

In part due to pressure from large companies as well as government and regulatory agencies that will increase the use of RFID, bar code technology, together with global satellite systems, and cellular technology will be used more and more to leverage event data, moving extended supply chain visibility closer and closer to actual real time. And beyond tracking, RFID technology tags can store vast amounts of data about a particular item and can even be used for security and climate control purposes.

All these areas are getting more relevant as technologies evolve, and devices, tags, and sensors get cheaper, so that more and more companies have already started to or at least are thinking of applying this for their businesses in the near future. This provides the opportunity to capture more and more accurate data for the SCEM solution, which enables more precise decision taking.

To meet the challenges of rapidly changing market dynamics, traditional linear supply chains and their sequential processes must be transformed into virtual communities or networks. These networks allow all participants – such as customers, suppliers, logistics providers, and so on – to sense changes in demand and supply conditions as they occur and to share the critical knowledge needed to respond intelligently. The result is an adaptive supply chain network that is not only demand driven, but can also leverage its assets to influence demand where appropriate. This requires a dynamic synchronization of demand-driven planning, logistics, and network execution based on real-time information. And sophisticated SCEM capabilities are an integral part of this.

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Supply Chain Risk Management: A Neural Network Approach

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Introduction

Effective supply chain risk management (Hallikas et al. 2002; Harland et al. 2003; Henke et al. 2006) requires the identification, assessment and monetization of risks and disruptions, as well as the determination of the probability of their occurrence and the development of alternative action plans in case of disruptions (cf. Zsidisin 2003; Zsidisin et al. 2004; Zsidisin et al. 2000; Vidal a. Goetschalckx, 2000). Companies traditionally use multiple sources for material procurement and/or hold safety stocks to avoid vulnerability. However, these strategies can negatively impact the supply chain performance, leading to higher purchase and logistics costs. The aim of this chapter is to illustrate how the implementation of the supply chain risk management concept can be improved by using a neural network approach.

The chapter is organized as follows: in the next section basic and theoretical concepts of supply chain risk management are presented. Section 3 outlines a framework for categorizing and analyzing risks in supply chains. In section 4, we present a neural network approach that can be applied to assess various risks in supply chains. In section 5 preliminary results of our neural network experiments are presented and discussed. In the final section some conclusions are drawn. We also provide recommendations for future research.

Supply Chain Risk Management – Theoretical Background

Since the mid-eighties the supply chain management concept has been discussed intensively in practice and within the scientific community.

However, besides enjoying successes, the supply chain management approach also faces new challenges (Barry 2004; Jung et al. 2004). The occurrence of new risks such as uncertain demand, the increasing vulnerability of supply chains due to trends such as globalization, saturation of markets or terrorist attacks have forced companies to establish new concepts for risk assessment. It is therefore necessary to define a "manageable" security/risk level which is ultimately a so-called trade-off between supply chain costs, security and performance (e.g. taking on responsibility in the case of disruptions in supply chains). Thus the supply chain management concept has to be enhanced by methods of complexity and risk management. Figure 1 illustrates the trade-off between supply chain costs and supply chain security.

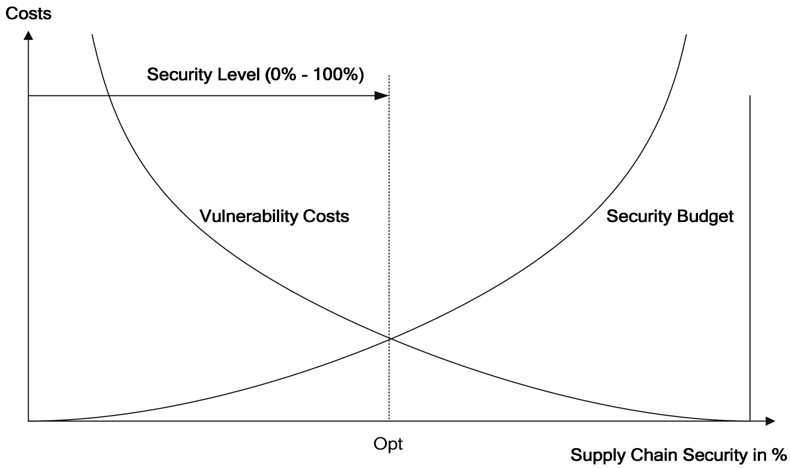

Fig. 1. The trade-off between supply chain security, vulnerability and costs (adapted from Teufel a. Erat 2001, p. 216)

In recent years, the notion of the term “risk” has been given greater attention in research on supply chain management both by academics and practitioners.
It is worth mentioning that 100% security or a 0% probability of risk occurrence is not possible in real-life supply chain scenarios. The goal is to determine a "manageable" security/risk level (denoted point *Opt* in Fig. 1).

The definition of the term "risk" strongly depends on the context and field of research involved (Spekman a. Davis 2004). An operational definition in the context of supply chain risk management is as follows: *"Risk is the product of the probability of occurrence of a (negative) event and the resulting amount of damage*". (Kersten et al. 2006, p. 5; March a. Shapira, 1987).

Risks within supply chains can be categorized into supply, process, demand, control and environmental risks in accordance with the SCOR (= Supply Chain Operation Reference) model processes *plan*, *source*, *make* and *deliver* developed by the non-profit organization SCC (Supply Chain Council) (cf. Fig. 2).

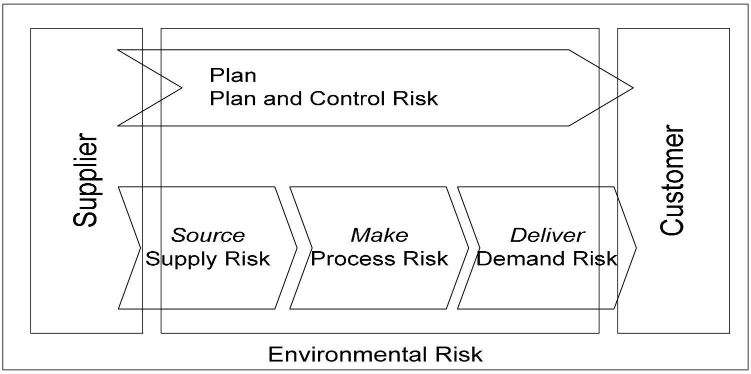

Fig. 2. Categories of risks in supply chains (cf. Kersten et al. 2006, p. 6)

The above-mentioned types of risks, risk drivers and their impacts are categorized in Table 1 (Chopra a. Sodhi 2004; van Wyk a. Baerwaldt 2005; Jahns et al. 2006. pp. 201-203).

Table 1. Categories of supply risks from the literature

Risk category	Risk driver	Risk impact
Plan and control risk	▪ Applied methods, concepts and tools ▪ IT systems (breakdown, introduction or change of IT systems, virus damage, change of interfaces, data loss)	▪ Opportunity costs ▪ Cost of capital ▪ Logistics costs
Supply risk	▪ Quality of material ▪ Suppliers (failure, single sourcing, adherence to delivery dates) ▪ Supplier dependence ▪ Global sourcing ▪ Supplier concentration ▪ Supply market ▪ Damage to cargo ▪ Monopoly situations (single sourcing) ▪ New strategic alignment of suppliers ▪ Illiquidity and insolvency of suppliers	▪ Production stop ▪ Replacement purchase costs ▪ Supply interruptions
Process risk	▪ Lead times ▪ Capacity bottleneck ▪ Output ▪ Quality ▪ Machine damage ▪ Human error ▪ Faulty planning ▪ Trouble with third-party logistics provider ▪ Major technological change	▪ Supply difficulties ▪ Repair costs
Demand risk	▪ Demand fluctuations ▪ Changes in preferences ▪ Cancellations ▪ Planning and communication flaws in sales	▪ Supply difficulties ▪ Safety stock (Bullwhip effect)

	department ▪ Inflexibility	
Environmental risk	▪ Natural disasters (fire, earthquake, flood, rock fall, landslide, avalanche, etc.) ▪ Weather (iciness, storm, heat) ▪ Political instability (strike, taxes, war, terrorist attacks, embargo, political labor conflicts, industrial disputes) ▪ Import or export controls ▪ Social and cultural grievances ▪ Crime ▪ Price and currency risks/inflation	▪ Opportunity costs ▪ Replacement costs

In 2004, the COSO (Committee of Sponsoring Organizations of the Treadway Commission) developed the so-called Enterprise Risk Management (ERM) Framework (cf. Fig. 3). ERM offers new methods to improve the risk management system in organizations (Henke et al. 2006, p. 97). Furthermore, it has become an important tool in the context of compliance, e.g. implementing directives in the context of the Sarbanes-Oxley Act of 2002. We will take the ERM Framework of COSO as a starting point for the proposed comprehensive Supply Chain Risk Management framework developed in this chapter.

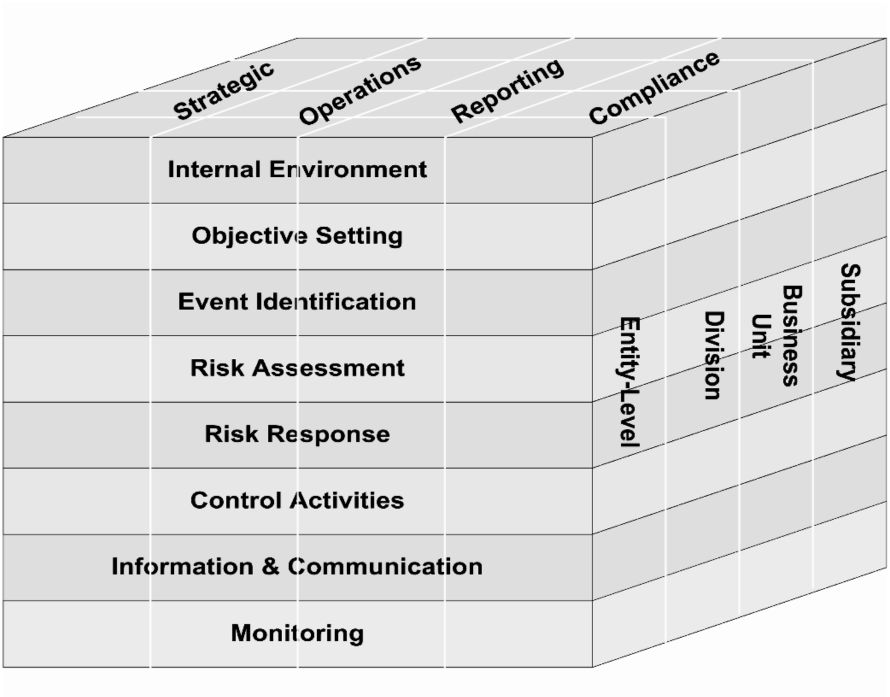

Fig. 3. Enterprise Risk Management (ERM) framework of COSO (COSO 2004)

Kersten et al. (2006) define supply chain risk management as *"a concept of Supply Chain Management, which contains all strategies and measures, all knowledge, all institutions, all processes and all technologies, which can be used on the technical, personal and organizational level to reduce supply chain risk"* (Kersten et al. 2006, p. 8).

As illustrated in Figure 4, rigorous supply chain risk management is a cyclic process encompassing the following six phases (Engelhardt-Nowitzki a. Zsifkovits, 2006, pp. 49-50; Jüttner 2006; Ritchie a. Brindley, 2007; Jahns a. Henke, 2004, pp. 38-44; Henke et al. 2006; Jahns et al. 2006, p. 197):

1) ***Formulation/Revision of Risk Strategy*****:** In this phase a risk strategy is defined that needs to be aligned with companies' corporate strategy. The risk strategy determines the risk management processes as well as the organizational structure and technological infrastructure. The risk strategy profile is based on past experiences and the estimation of future risks that may occur.
2) ***Risk Identification & Monitoring:*** This phase includes the identification of stakeholders and objectives to create initial awareness of potential supply chain risks as well as the continuous monitoring of supply chain processes to anticipate disruptions before they occur (cf. Smeltzer a. Siferd, 1998).
3) ***Risk Analysis, Prioritization and Assessment:*** This phase requires the assessment, prioritization and monetization of risks in order to make them more operational for basing decisions on. Risk analysis and prioritization by risk impact, probability, risk level and other criteria, as indicated in Table 2, help us focus on the most critical supply chain risks.
4) ***Risk Response and Action Planning & Scheduling*****:** This phase includes risk action planning and scheduling in order to react adequately to disruptions. The risks to be monitored will be assigned with the appropriate handling options (e.g. avoidance, transfer, prevention, acceptance or mitigation) (cf. Müssigmann 2006, p. 215).
5) ***Risk Controlling:*** This phase includes status reporting on the execution of risk action plans as well as risk tracking and tracing in terms of probability, impact and other risk metrics. The progress of the risk situation in their respective risk action plans is analyzed.
6) ***Comparison of Risk Situation and Risk Strategy*****:** Learning from previous disruptions plays an important role in this phase. The knowledge gained in previous phases is used to draw up risk reports and compare the current risk situation with the risk strategy in order to adopt it. In future, certain risks may be managed in a more appropriate manner.

It is worth mentioning that the above-described phases do not necessarily have to be conducted in a sequential order; phases are often performed iteratively or even simultaneously.

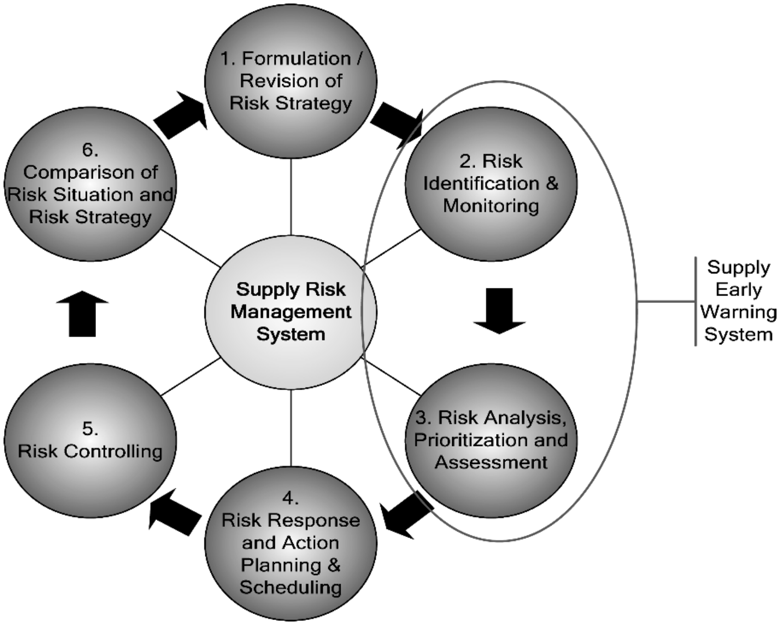

Fig. 4. Supply Chain Risk Management System (adapted from Jahns a. Henke 2004, pp. 38-44; Henke et al. 2006; Jahns et al. 2006, p. 197)

In Figure 4 the position of the subsystem "supply early warning system" is highlighted. This subsystem in the overall supply risk management system includes all methods and techniques that are applied to identify, analyze, control and assess supply chain risks (Jahns et al. 2006, p. 199).

A Framework for Analyzing and Assessing Risks in Supply Chains

Identification of disruptions plays an important role in the assessment of supply chain risks (Teuteberg a. Ickerott 2007). In Table 2, we classify disruptions by means of several criteria in a morphological box. Morphological analysis was developed by Fritz Zwicky in the late sixties (Zwicky 1969) for multi-dimensional, non-quantifiable socio-technical systems and problems.

For example, a differentiation can be made between unplanned and standard disruptions (e.g. order change), unplanned and non-standard disruptions (e.g. lost shipment, natural disaster), planned and standard disruptions (e.g. change of production machines) and planned and non-standard disruptions (e.g. transport strike). In 2000, for example, a fire damaged the plant of Nokia's and Ericsson's main supplier, which delivers mobile phone components. For illustration, we classify this specific event "Plant fire" by means of our morphological box for disruption classification (see Table 2).

Table 2. Disruption classification & assessment (adapted from Teuteberg a. Ickerott 2007, p. 96)

Criteria	**Attributes**					
Category	planned	unplanned				
Type	standard	non-standard				
Frequency of disruption	minutely	hourly	daily	weekly	monthly	yearly
Duration of disruption	short	medium	long			
Severity of disruption	negligible	minor	routine	serious	critical	catastrophe
Probability of occurrence	unlikely	seldom	occasional	likely	frequent	
Cost/Disruption	low	medium	high			
Time/Disruption	low	medium	high			
Resources/ Disruption	low	medium	high			
Disruption producer	unknown	known				
Appropriate response personnel/experts	Internal	External				
Disruption Process Level (SCOR)	Operations Strategy (SCOR Level 1)	Intra- and Inter-Company Configuration (SCOR Level 2)	Intra- and Inter-Company Process, Practise and System Configuration Elements (SCOR Level 3)	Intra- and Inter-Company Supply Chain Improvements (SCOR Level 4)		
Location of disruption	Near to suppliers	Internal focus	Near to customers	Dual focus (pooling of responsibilities)		
SC Planning Influence	Short-term plans	Master plans	Aggregate plans	Logistics strategy plans	Business strategy plans	Corporate strategy plans
SC Flow Level	Information flow	Goods flow	Cash flow			
Recommended actions	Acceptance	Avoidance	Assurance	Make or buy	Activity	

In recent years, the so-called risk map (risk portfolio) is often used to assess risks in supply chains. Figure 5 illustrates such a risk map, containing four types of risk responses (action steps) with regard to the likelihood of risk occurrence and the risk impact:

1) *Risk acceptance*: Risks that occur very seldom and that have a small impact can be accepted.
2) *Risk assurance* (transfer): Certain risks can be transferred to assurance companies.
3) *Make or buy (outsourcing):* Risk management activities can be conducted by the company itself or can be outsourced to third-party logistics providers.
4) *Activity:* Risk can be mitigated by avoiding or reducing risky activities as well as by reducing and preventing risks (e.g. training and education of employees).

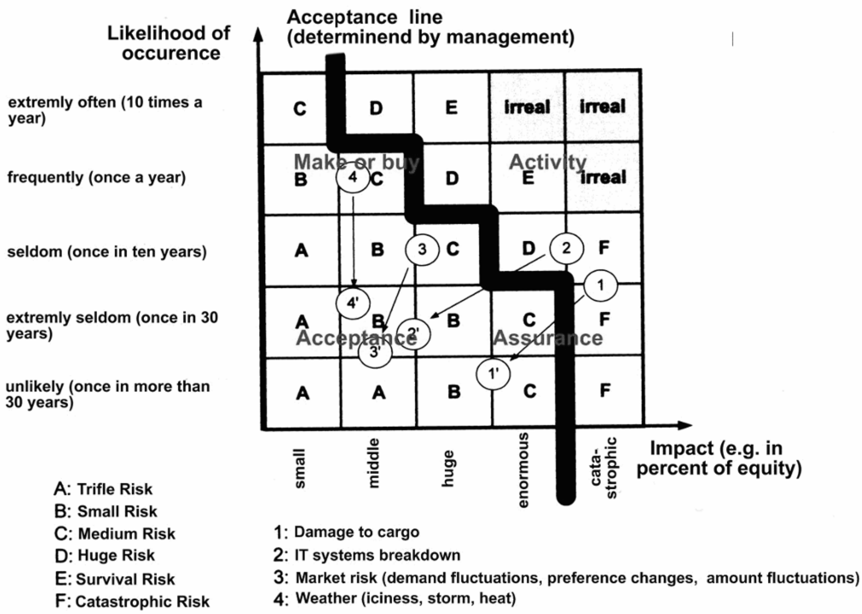

Fig. 5. Risk map (adapted from Königs 2006, p. 17)

The overall process of managing risks in supply chains is illustrated in Figure 6. The risk strategy (1), the development of security guidelines and risk metrics (2) as well as the following factors strongly influence the supply chain risk management system (3) and the implementation, planning and scheduling of action steps (4):

- *Political factors:* Political risks may originate from unstable political systems, a lack of political transparency, governmental business regulations and political conflicts.
- *Economic factors:* Economic risks may include globalization issues and growing markets (e.g. in China or Russia).
- *Social factors:* Social risks may originate from social disasters such as health pandemics (e.g. SARS) and terrorist attacks.

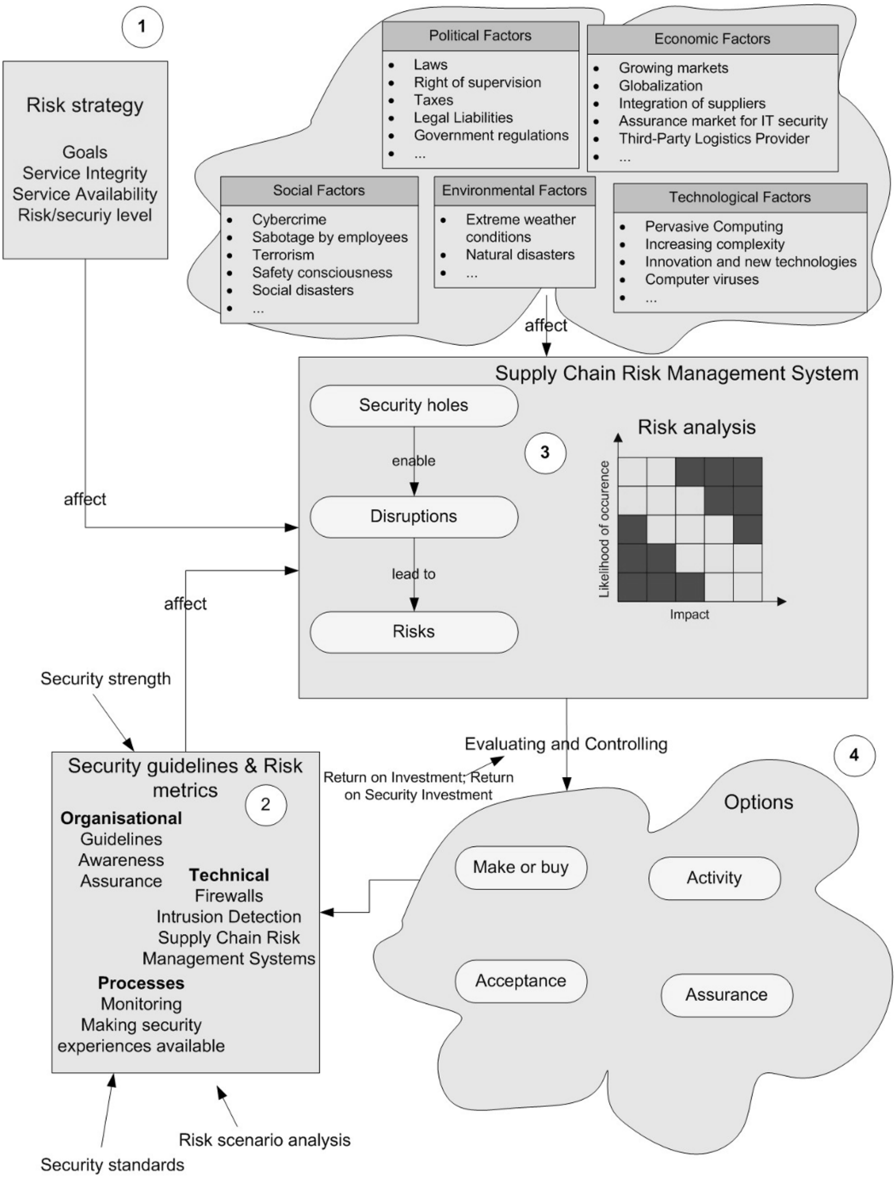

Fig. 6. Supply Chain Risk Management Framework (adapted from Müßig 2006, p. 42)

- *Environmental factors:* Environmental risks may arise from natural disasters such as earthquakes and extreme weather conditions (e.g. iciness).
- *Technological factors:* Technological risks may originate from IT failures, IT breakdowns or power cuts.

Supply Chain Monitoring – Risk Assessment Metrics

In order to monitor processes and disruptions in the supply chain to identify risks with regard to risk anticipation and avoidance, a risk measurement system needs to be implemented (Kleijnen a. Smits 2003; Svensson 2000). Metrics as quantitative risk indicators can be used to ensure an acceptable level of risk.
The key questions are:

- Which risk assessment metrics should be considered?
- How should they be used as guidelines for the formulation/revision of risk strategy?

Various metrics (risk indicators) that help quantify possible risk factors can be established in supply chain risk management (cf. Wisner et al. 2005, p. 66; Brewer a. Speh, 2000; Chan a. Qi 2003). Table 3 gives an overview of metrics that can be applied. In our neural network approach we use the metrics in Table 3 as input values for our neural networks.

Table 3. Risk Metrics (Indicators)

Metric	**Example (Risk Indicator)**
Cost/Price/ Financial	• Mean costs of production logistics per production order • Mean costs of transport per production order • Cost breakdowns • Willingness to negotiate price • Inventory cost, Transportation cost • Total cash flow, Rate of return on investment • Costs of defects, rework and problem-solving associated with purchases
Quality	• Degree of service, Complaint rate • Proportion of defects, Proportion of statistical process controls • Actual quality compared to: historical quality, specification quality, target quality
Delivery	• Delivery reliability/on-time delivery, Delivery quantity reliability • Delivery quality reliability/defect-free deliveries • Confirmation rate of customer's desired delivery date • Actual delivery compared to: promised delivery • Extent of co-operation leading to improved delivery, Changes in delivery schedules • Request, filled, prepared, delivered time, Transit type (airway, seaway, etc.)
Responsive-ness and Flexibility	• Mean throughput time at goods exit • Order picking items per employee hour • Market reaction elasticity • Outstanding days payable • Average lead time • Ability to solve emergency problems in time

	• Responsiveness to customers/Responsiveness to changing situations • Degree of participation in new product development
Environment	• Degree of environmental responsibility • Environmental management system such as ISO 14000 • Extent of co-operation leading to improved environmental issues
Structure/ Organization	• Number of externally sourced articles, Number of customers, Number of suppliers • Proportion of quality inspections at goods arrival • Ratio of personnel costs/materials costs in logistics • Mean planned replacement time, Storage quota for raw materials • Turnover rate of the total inventory, Turnover rate for circulating material • Number of source material per product, Number of products • Proportion of logistics area, Proportion of external transport • Employee fluctuations • Reliability of supply network partner

A Neural Network Approach for Supply Chain Risk Management

By means of the proposed neural network approach, critical paths within a supply network can be anticipated (see Fig. 7). To determine the critical paths for each node and for each link in a supply network, a vector of risk metrics (see Table 3) has to be calculated. Nodes or edges (transport paths) are critical if their risk level is higher than a threshold value (e.g. risk level > 0.75), predefined in the risk strategy phase.

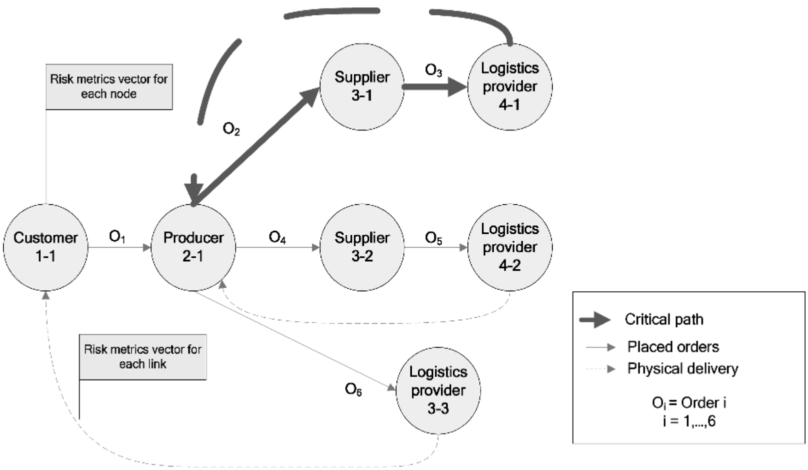

Fig. 7. Supply Network with critical path

For example, neural networks can be applied to calculate the probability of risk occurrence between the nodes of the supply network or at a specific node, as illustrated in Table 4, taking various risk metrics as input vectors. In Table 4, values with a risk level (probability of disruption occurrence) > 0.5 are highlighted in bold. In our example in Figure 7 and Table 4, a critical path can be determined between Producer 2-1, Supplier 3-1 and Logistics provider 4-1, because the risk level for each node and link is > 0.5.

Table 4. Risk Assessment Matrix

	Probability of disruptions at a specific link							**…at a specific node**
	1-1	2-1	3-1	3-2	3-3	4-1	4-2	
1-1	0	0.465	0.413	0.357	0.345	0.005	0.467	0.478
2-1	0.345	0	**0.976**	0.471	0.453	0.456	0.436	**0.599**
3-1	0.435	0.368	0	0.481	0.334	**0.911**	0.412	**0.612**
3-2	0.123	0.231	0.462	0	0.442	0.432	0.239	0.399
3-3	0.478	0.490	0.390	0.444	0	0.333	0.267	0.346
4-1	0.345	**0.957**	0.456	0.327	0.429	0	0.331	**0.685**
4-2	0.045	0.127	0.235	0.455	0.342	0.124	0	0.345

After identifying and visualizing critical nodes and edges in supply networks, appropriate action steps have to be considered (e.g. acceptance, avoidance, reduction, prevention, transfer (assurance), make or buy). For this purpose, nodes and edges can be transformed and visualized into the risk map (cf. section 3) using the probability of risk (disruption) occurrence and the risk impact (both values estimated by means of neural networks (cf. next section) as the x- and y-axis.

Neural Networks

Neural networks (for an introduction see Lippman 1987) are useful for solving classification problems and are well suited for complex information processing problems, since they are capable of learning from noisy data and generalizing (Bishop 1995). The first neural network model (perceptron) was developed by Rosenblatt in the late 1950s (Wassermann 1989). Since then, neural networks have been applied to various classification and prediction problems, for example in time series forecasting, stock market prediction, supply chain planning and pattern recognition (Bishop 1995; Bansal et al. 1998; Chiu a. Lin 2004; Vellidoa et al. 1999). Neural networks that are inspired by biological nervous systems can be described as a directed, weighted graph consisting of three or more layers: one input layer, one or more hidden layers and an output layer (see Fig. 8). The arcs represent the weighted connections between the processing elements (nodes). The nodes of the neural network are called neurons, which operate in parallel. w_{ij} is the weight of the connection between neuron i and neuron j.

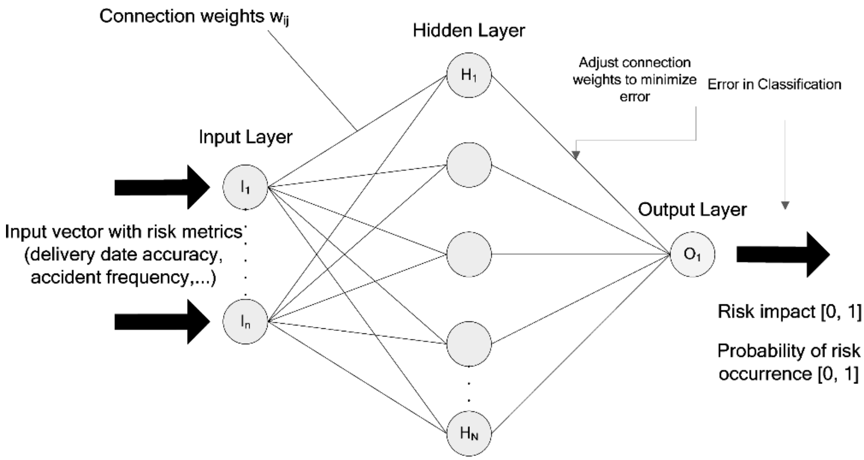

Fig. 8. Neural Network with one hidden layer

Figure 9 illustrates the three-step information processing sequence inside a neuron.

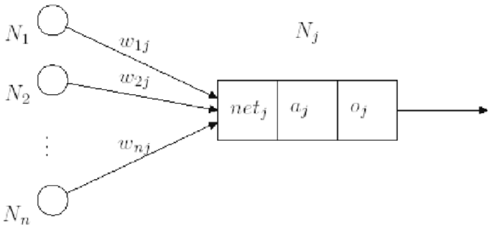

Fig. 9. Information processing in neurons (Wilbert 1996, p. 52)

All inputs, which themselves are also outputs of previous neurons, are multiplied with the associated weights and aggregated to a single value *net*$_j$, as shown in equation (1.1). This value *net*$_j$ is passed on to the activation function, as shown in equation (1.2). Commonly used types of activation and output functions, respectively, include linear, quadratic or sigmoid functions. The new activation state of a neuron is a result based on the previous state and the net input. In the last step, the newly calculated activation state is used to compute the final output o_j, as shown in equation (1.3).

$$\mathrm{net}_j = \sum_i o_j \times w_{ij} \qquad (1.1)$$

$$a_j(t+1) = F_j(a_j(t), \mathrm{net}_j(t)) \qquad (1.2)$$

$$o_j = f_j(a_j) \qquad (1.3)$$

The input layer contains a number of elements that pass weighted inputs to the neurons of the hidden layer, according to the connection weights. Inputs to the neurons in our problem are risk metrics, as listed in Table 3. The neurons in the hidden layer process their inputs and propagate their outputs to the output layer, which produces the network’s response. Outputs in our case are the probability of risk occurrence or the risk impact calculated in the intervals [0, 1]. Commonly, neural networks are trained so that a particular input leads to a specific target output. This adjusting (training) process is called *supervised learning*. Training means adjusting the values of the connections (weights) between the neurons.

Preliminary Experimental Results

The multi-layer perceptron (MLP) is the basic model of the work reported here. A simple MLP consists of three layers: an input layer, a hidden layer and an output layer. A commercial neural network simulation tool called *NeuroSolutions* (www.nd.com) was applied to implement the networks. NeuroSolutions provides several options with regard to learning algorithms, the number of neurons, the number of hidden layers, and other network parameters, which can be set by the user via a graphical editor. The software can be run within Excel, exploiting Excel's power and facilities for importing risk profiles as well as exporting and interpreting neural network results.

For our experiments we use a demonstration model of a supply network, delivered by the commercial simulation software called *Flexsim* (www.flexsim.com). The Flexsim supply network consists of three locations in Vancouver, Florida and California which order various helicopter parts. These parts were delivered by two distribution centers, two local trans-shipment centers and an original equipment manufacturer. The selection of suppliers depends on their availability. Transport of helicopter parts is possible both by air and via seaway.
Figure 10 illustrates the above-described supply network. In our experiments we anticipate the risk of orders by one node of the supply network via a specific transport way (airway, seaway). Based on several risk metrics, orders were considered “risky” (output value 1) or “not risky” (output value 0).

During simulation the Flexsim supply network demo generates data that can be exported in Excel spreadsheets as input vectors for our neural network simulator NeuroSolutions. In the training phase, a set of data, as illustrated in the Excel spreadsheet in Figure 11, is given as input to the neural network. The weights of the neural connections are adjusted such that the output of the network approximates the desired output (e.g. 0 or 1). To set the weights, the mean squared error (MSE) is computed. The MSE is the sum of the squared differences between the desired output and the actual output of the output neurons averaged over all training exemplars. A small value (e.g. close to zero) indicates that the network has learned well and is suited to the classification problem.

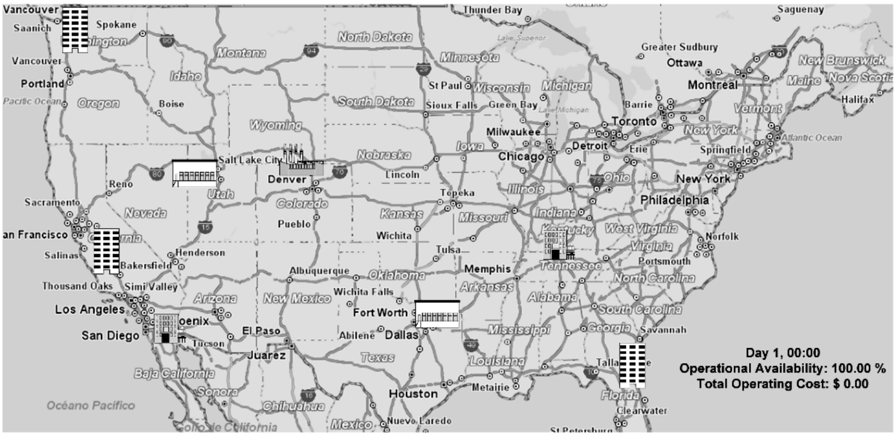

Fig. 10. Supply network demonstration of Flexsim

Risk metrics as outlined in Table 3 are coded and represented in Excel spreadsheets. Figure 11 shows an excerpt from such an Excel spreadsheet. Each row describes one input vector (risk profile). The columns contain the risk metrics. In real-life application scenarios such risk profile data can be automatically generated via sensor networks, data warehouses, ERP systems, global positioning systems and Auto-ID/RFID systems.

For our experiments we use the data of 20 simulation days in Flexsim. The first 15 simulation days are used as training data and the next five days are used as test data for our neural networks. Thus we can train and test our neural networks with 424 input vectors (106 for testing and 318 for training the networks).

	A	B	C	D	E	F	G	H	I	J	K	L
1	part ID	requesting station index	part priority	request time	filled time	prepared time	shipped time	providing station index	shipment number	transit type	delivered time	reason for starting travel
2	3	2	2	3,5388	3,5388	4,5388	4,5388	4	1	2	17,2804	2
3	3	4	2	3,5388	42,9476	43,9476	43,9476	7	32	2	56,3864	2
4	5	1	1	3,6012	3,6012	4,6012	4,6012	4	2	1	11,5394	1
5	5	4	3	3,6012	3,6012	4,6012	7,936	6	3	2	28,2822	2
6	5	6	3	3,6012	44,4784	45,4784	61,0473	8	33	2	69,7434	2
7	10	1	1	6,3352	7,3352	8,3352	8,3352	6	6	1	24,4989	1
8	11	1	2	6,936	6,936	7,936	7,936	4	4	2	21,9998	2
9	11	4	2	6,936	6,936	7,936	7,936	6	3	2	28,2822	2
10	11	6	2	6,936	17,1623	18,1623	18.1623	8	14	2	26,9595	2

Fig. 11. Excerpt of the Excel spreadsheet with input vectors

Table 5 shows the best training and testing results from our experiments with multi-layer perceptron networks. The MLP with four hidden layers and 75 neurons in each hidden layer turned out to be the winner. When this network was run to classify the training set, 94.2 of all risk profiles were classified correctly.

In our experiments, we applied MLP networks with one, two, three and four hidden layers and linear activation functions for the input and output layer. For the hidden layers we applied sigmoid activation functions (see the first three columns in Table 5). Additionally, we chose an indifferent window by means of the following rule to improve classification accuracy: *If output value > 0.75 then disruption will occur, else no disruption will occur at a supply network node/link.* Correct classification means a disruption has occurred at a specific link or node in our simulation and the neural network has anticipated this disruption correctly (e.g. output value > 0.75). Correct classification also means that no disruption has occurred and the neural network has also diagnosed this case correctly. The test data (last column of table 3) are unknown and have not been presented as input vectors for the neural networks before. Thus, the classification rate is not as good as with training data.

Table 5. Preliminary classification results from training and testing neural networks

Layers Activation function			**Correct classification Data sets (training)**	**Correct classification Data sets (test)**
In	**Hidden**	**Out**		
linear	1 sigmoid	linear	92.3%	83.8%
linear	2 sigmoid	linear	91.4%	82.7%
linear	3 sigmoid	linear	93.3%	84.7%
linear	4 sigmoid	linear	94.2%	86.6%

Our neural network training process was not as time-consuming as often claimed in the literature (in our experiments, it took less than ten minutes for 318 training data sets). Performance of the neural networks was also very good. Trained neural networks generate an output in less than 3 seconds when an unknown input vector with risk metrics is given as input for the input layer. Many other application scenarios of neural networks for supply chain risk management can also be considered. We are currently estimating suppliers' delivery times by means of neural networks and are ranking suppliers based on several supplier metrics (e.g. delivery costs, delivery time, etc.).

Neural Network Approach – Pros and Cons

Table 6 summarizes the pros and cons of our proposed neural network approach for supply chain risk management.

Table 6. Pros and cons of the neural network approach

Pros	Cons
▪ Neural networks learn from real-life cases (like a human brain) ▪ Anticipation of disruptions and risks is possible (even risk impact can be estimated) ▪ A "learning" supply network represented by a learning neural network can be established ▪ Neural networks determine coherences between risk metrics and the occurrence of disruptions ▪ Neural networks are flexible and can be adjusted to new risk scenarios ▪ They are capable of learning from noisy data and of generalizing ▪ Neural networks are very well suited for complex information processing	▪ Selection of appropriate training data is difficult ▪ Coding of training and test data sets ▪ Neural network is a “black box” (output results are not intuitive and sometimes difficult to interpret) ▪ The number of nodes in the hidden layer(s) and the number of hidden layers has to be determined via experimentation in a “trial-and-error” process (no criteria for the ”optimal” design of a neural network in a specific application domain) ▪ Too many nodes lead to overfitting. On the other hand, too few nodes reduce classification accuracy

Correlations (interdependencies) between risk metrics (indicators) are difficult to detect by supply chain decision-makers. For this reason, a rule-based approach in supply chain risk management is not the first choice. Instead, neural networks are capable of learning from past disruptions and are more flexible than static if-then rules (e.g. if delivery time is > 2 hours then…). By applying our neural network approach supply network members can

- understand the supply risk that exists,
- proactively assess the probability and impact of supply risk in advance,
- reactively learn from disruptions that occurred in the past and can thus improve their supply chain risk management system.

Conclusions and Future Research

In this chapter, a supply chain risk management approach based on neural networks was presented. Our first aim was to classify risk profiles of supply network nodes and links (transportation paths). For this purpose, several MLP networks were tried. All networks performed quite well. The winner, an MLP with three hidden layers and 75 neurons per hidden layer, exhibited reasonable generalization capability. When exposed to new data sets (unknown risk profiles), it classified 86.6% on average correctly. Today, the automatic observation and management of disruptions and other irregularities in supply networks is generally limited to single supply chain members. The neural network approach presented in this chapter is intended to integrate data from single members so that all members can assess and visualize risk profiles.

In this final section, we would like to discuss a number of problems and topics for further research in supply chain risk management based on neural networks. Challenges still to be solved include (Teuteberg a. Ickerott, 2007, p. 120):

- *Information overflow:* The mass of products, machine data and other resources that have to be scanned and transmitted in a supply network have to be managed in time-critical processes due to constraints in available bandwidth and computing power (Angeles 2005, p. 55).
- *Lack of co-operation:* Although our proposed approach provides a promising method of risk management in supply networks, supply network nodes can still refuse to share their information (risk profiles) with their partners.
- *Lack of honesty and hiding of information:* Supply chain partners could hide important information (e.g. data about disruptions) from each other in order to optimize individual utility, or they may be dishonest. Or else they may believe that they can solve problems before they start affecting other supply network members and may wait instead of alarming other members immediately. Thus, trust is an important prerequisite in our approach for transmitting risk metrics between supply network partners.

In future, it is intended to simulate typical business processes in supply networks and conduct neural network experiments based on real-world data (risk profiles) from business partners in order to see if our approach performs well in real-life, too.

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Performance Management in the Value Chain

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Introduction

Performance management in the value chain is a critical task for companies confronted with increasingly complex global value chain networks. Managing global material flow and shipments between continents, tracking prices and volumes in global customer and supplier markets, and ensuring reliable and timely delivery of orders are only a few issues that can benefit from professional value chain management concepts. Performance management, one management concept in the value chain, includes strategic, tactical and operative concepts to measure and monitor as well as ensure performance and stability in the value chain. Value chain performance should be tracked regularly and measured transparently, and exceptions and unplanned events should be proactively identified and managed. The objective of this article is to provide a practice-oriented view of performance management in the value chain as well as current frameworks and industry case examples.

Value Chain Management

The value chain is a company model developed by Porter (see Porter 1985) focusing on cross-functional orientation in the company. Porter's value chain model is structured by primary activities such as service, marketing and sales, operations, and outbound and inbound logistics and support activities such as procurement, technology development, human resource management and company infrastructure. Companies used to concentrate on the management within these individual functions instead of focusing on cross-functional value chain optimization. Therefore, value chain management focuses on optimizing volumes and values based on cross-functional management concepts and integrated decision making throughout the value chain (Schulz et al. 2007).

Complexity is one major reason why these efforts are slowed or often difficult to implement. Different departments, and different suppliers and customers, are involved and must work together cooperatively to manage the value chain successfully. Therefore, companies typically follow a three-stage evolutionary path from supply chain to value chain management.

The first stage is characterized by the internal management of company functions such as sales, marketing, production, logistics and procurement. This focus on function can reflect the best result in a single area but not necessarily the best result for the entire value chain. For example, in procurement, long-term purchasing contracts with high volumes can help to achieve minimum costs. However, binding contracts can lead to high inventories and additional logistics costs if contracted raw material volumes will not be fully used in production because there is a lack of demand for finished products.

In the second stage, the supply chain can be optimized by more integrated decision making. Supply chain management as a concept is widely discussed in theory and applied in practice (Stadtler 2004). The core idea of supply chain management is to manage integrated flows of material and information within the company but also between and among companies in order to minimize inventories and achieve optimum utilization of production resources. Therefore, the objective of supply chain management is to minimize the supply chain costs, to deliver a defined service level and to meet customer demand. Supply chain management focuses therefore on integrating decision making on production and distribution volumes. Volume and specifically price decisions in sales and procurement are often not in scope and considered as given. Without an integrated approach however, costs minimized in supply chain management do not automatically produce the best profits for the company.

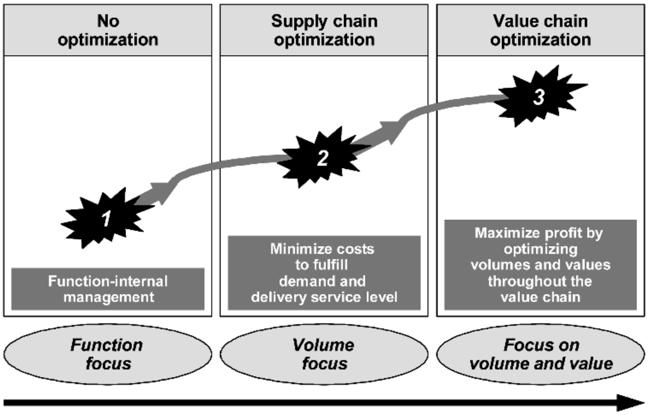

Fig. 1. The evolution towards value chain management

The third step in the evolution of managing the value chain is value chain optimization. Optimization means integrating all volume and value decisions to maximize profits across the entire value chain from sales to procurement. An optimized value chain is a milestone for a company because it means managing profitability, volume flows and services in a future-oriented manner (Fig. 1).

The Framework of Value Chain Management

Value chain management is based on an integrated framework in which processes and management concepts to manage the value chain are included. The value chain is structured according to the company's key functions sales, distribution, production and procurement; it also includes dedicated negotiation and collaboration interfaces with suppliers and customers. The framework makes a distinction between:

1. The process view, which deals with strategy, planning and operations processes at the *strategic*, *tactical* and *operative* levels respectively; and
2. A required management basis, which includes performance management, organization, and information technology (IT) (Fig. 2).

Value chain strategy covers *strategic* decisions that determine a company's value chain network. These might include investments in new production facilities, explorations of new markets or strategic sourcing alliances. The strategy also determines business rules for planning the value chain network volume and values such as inventory boundaries, minimum market share targets, procurement contract limits and production parameters such as capacities and minimum utilization. The value chain strategy defines the network and network planning rules and is conducted e.g. annually with a horizon of one to several years. Value chain planning is the *tactical* process usually carried out monthly; this process is also known as sales and operations planning (S&OP). The objective of value chain planning is to determine the volumes and values in the company's value chain network. Most important in the planning process is integrated decision making about all volumes and values: sales, distribution, production and procurement. Sales volumes, transportation and inventory quantities, production and procurement quantities, and prices and costs should be included. Value chain operations is the *operative* integration of all order schedules in the value chain. Production schedules must be synchronized with customer and transportation orders and purchase orders. Value chain operation processes, such as customer or purchase order management, are based on the value chain plan with defined volumes and values to ensure the stability of value chain operations. All three process levels share a common management basis in performance management, organization and IT. A value chain management organization includes roles and teams that run the value chain processes.

Information technology is required specifically to plan and operate complex global value chain networks in an automated way and to ensure data consistency and integration among process levels as well as decision support.

Finally, performance management is the element of the value chain concept that includes the elements cockpit, monitoring and event management to reach performance transparency and react in case of unplanned events.

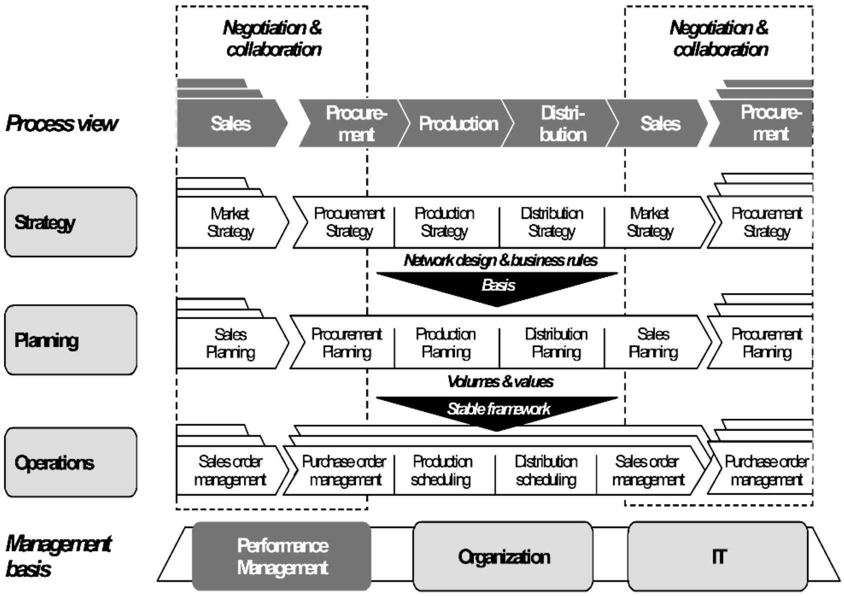

Fig. 2. The value chain management framework

To summarize, the focus of value chain management should be on the most profitable businesses, while less profitable businesses receive lower priority as they compete for internal resources. Such concepts are well known on a business unit level. The challenge is to introduce these concepts into strategic decision making, tactical planning and day-to-day operations. Applying this value chain management framework in a holistic and consistent way, the company becomes more agile and better able to take advantage of the most promising business opportunities on an ongoing basis.

Performance Management Concepts in the Value Chain

Managing performance in the value chain can be matched to the process level in the value chain management framework. A cockpit can be used to manage performance related to strategic and tactical concepts, while value chain monitoring and event management are the preferred concepts on the level of operations. Management uses a cockpit to obtain transparency on the overall performance of the value chain with a global or regional focus; updates are required on a quarterly or even monthly basis. The cockpit concentrates on aggregated results; for example, the focus is on the quality of global planning or overall utilization instead of the detailed results of individual transactions and orders.

Compared with value chain monitoring, event management focuses more on detailed events that occur in daily operations, for example in order management, payment, production and shipments.

Confronted with thousands of transactions, monitoring and event management require automated approaches and standard escalation procedures to ensure stability in daily operations (Fig. 3).

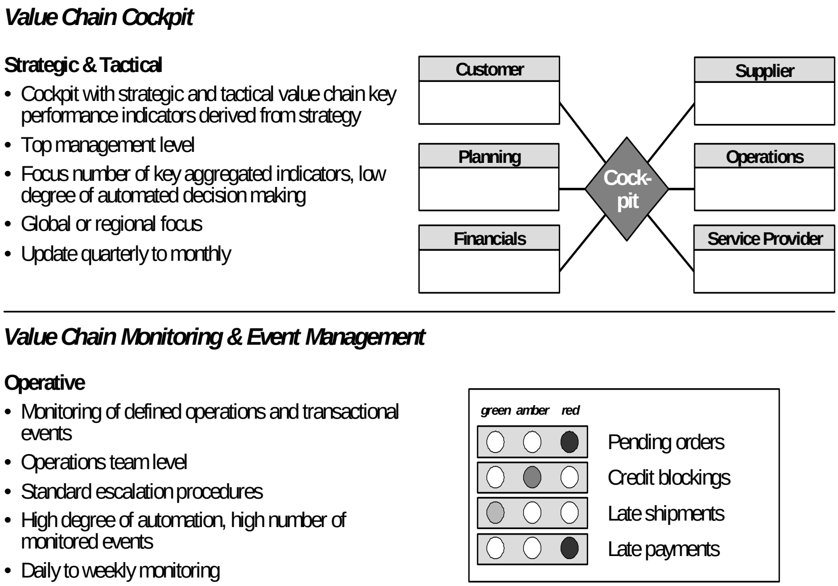

Fig. 3. The value chain performance management framework

Both concepts are required to ensure the overall performance and stability of the value chain. However, it is critical to differentiate strategic, tactical and operative layers when designing performance management concepts, which are detailed in the following.

The Value Chain Cockpit

The value chain cockpit consists of a number of key performance indicators (KPIs) to steer the value chain on the strategic and tactical levels (Fig. 4). First, the KPIs are derived from the company's business and value chain strategy for meeting objectives and measuring achievement. A premium supplier strategy, for example, requires different objectives and KPIs than a global cost leadership strategy.

Examples of KPIs depend on industries, utilization, customer satisfaction, profits and costs. KPI categories need to cover financial and non-financial as well as leading and lagging indicators in order to provide a balanced view of performance. According to these categories, all KPIs are consolidated into a scorecard that provides a stable framework for balanced performance management. Since KPIs are an inherent part of the target agreement, the value chain cockpit plays an important role in the entire process.

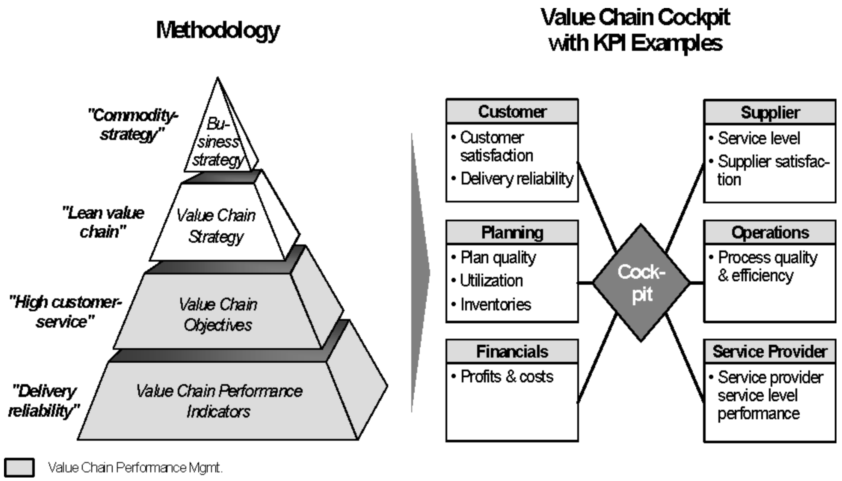

Fig. 4. The value chain cockpit

The number of key performance indicators should be limited, focusing on action orientation and meaningful measures. Otherwise, overly detailed reports will lead to high complexity in management decisions. The cockpit requires IT support such as a data warehouse. However, decision making to influence KPIs and to reach defined target values can rarely be automated. When important business decisions need to be made, software providers and researchers should be defensive in developing automated solutions or even agent-based decision-making frameworks. IT should not replace decision making by the company's CEO. The terrain of automated IT solutions is more appropriate to performance management concepts such as operations monitoring and event management.

Value Chain Monitoring and Event Management

Value chain monitoring and event management ensure the stability of the value chain in daily operations.

Teams such as customer service or material management have to handle thousands of transactions such as purchase, production or customer orders in a year's time. Unplanned events always occur in these transactions, leading to delays or even cancellations of orders. These events can be attributed to various factors, such as losses incurred by a broken framework contract, delayed delivery of a time-critical order or negative effects on perishable foods in case of troubles within the distribution chain of cold products. These are only a few of many possible events. Because of their unpredictability, the events are a big challenge for a company since neither their timing, duration, type nor volume can be always anticipated and only evaluated using statistical analysis. One thing they all have in common is that they destabilize value chain operations and may have a negative impact on company profits. This is a danger for every company, which needs to put these events on its watch list.

Therefore, value chain monitoring and event management are built up in a structured approach that begins with the definition of the events to be monitored. Escalation procedures and responsibilities are derived from business rules and thresholds. For example, customer service is responsible for monitoring orders with credit blocking, since orders cannot be processed if the customer's credit limit has been reached. Thresholds are set to check the timeframe of the blocked order and in a case such as this an immediate resolution must be found. Either the customer's delivery requirements will still be met or the customer will need to agree on cancellation since the outstanding debt must first be paid. In the next step, requirements for IT support and automation can be formulated and implemented. These might be required queries, red light mechanisms, alert mechanisms and, if feasible, automated resolution. But here as well, business-to-business orders can have significant value. Confidence in automated or agent-based decision making is often low, and the responsible employees prefer to have manual interaction when unplanned events occur. Software providers and researchers therefore should develop pragmatic and user-oriented solutions. Automated decision making should be designed and used only when its benefits and time savings are higher than the possible risk of an employee's not having made a personal decision (Fig. 5).

In the sections above, we have introduced practice-oriented value chain management and performance management concepts. Their application in industry practice and the precise problems they present are highly dependent on industry specifics. In the following section, we use three industry case studies to demonstrate the different priorities in value chain and performance management.

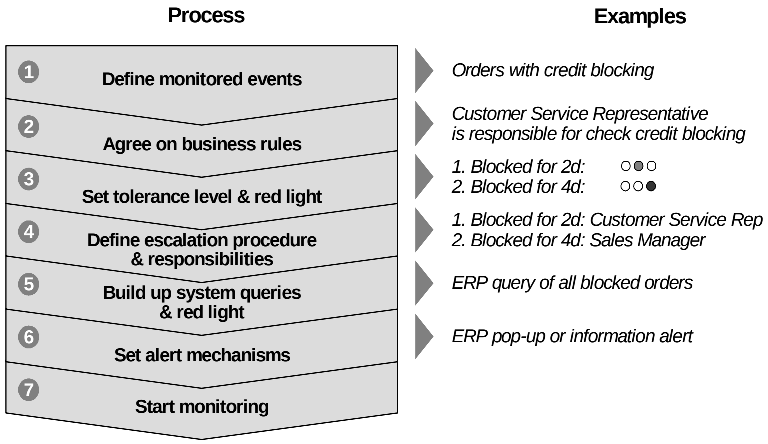

Fig. 5. Value chain monitoring and event management

Industry Case Studies

The following case studies focus on the chemical industry, the fresh food industry and the retail sector. In principle, all three cases deal with inventories, although they differ in focus. The chemical industry case focuses on capital costs and fluctuating inventory values driven by volatile raw material costs that require specific monitoring and event management processes. In the fresh food industry, on the other hand, the management of shelf life is critical, requiring the integration of shelf life into value chain planning and monitoring. Finally, the retail sector example involves management of a complex assortment of more than 10,000 stock keeping units in a supermarket. These three disparate industries have their own strategic, tactical and operative requirements for value chain management and monitoring. Specifics are discussed in the following section.

Inventory Monitoring in the Chemical Industry

The function of the chemical industry is to supply many basic raw materials to different industries. Its product portfolio ranges from commodities such as basic chemicals and intermediates or standard polymers to specialties such as fine chemicals for food, pharmaceuticals, cosmetics or agriculture products, to name a few. The chemical industry is often characterized by production assets that are extremely capital-intensive, and it requires managing the substantial flow of goods (volume and value) in global, regional and local networks.

This industry is confronted with the opportunities and challenges of globalization and its increased complexity and competition. The management of global value chain networks must ensure profitability and deal with volatile prices for crude oil and natural gas-based raw materials.

In the context of the chemical industry, value chain management is a central framework used to guarantee the profitability and stability of volume flows in a global chemical value chain network that interfaces with suppliers and customers. Within this network, all management processes involving strategy, planning and operations are relevant, as are performance management, organization and IT. Specifically, the management of production and distribution volumes and values is critical. Capital-intensive production assets must be utilized in the most effective way possible, and working capital, particularly warehoused inventories, require professional management and monitoring.

Average inventory volumes in a global bulk chemical business can easily reach 100,000 tons, with inventory values amounting to several million Euros. Optimizing inventory volumes and values has a direct impact on delivery service and capability, as well as a company's return on its capital investment. The chemical industry needs to consider and manage several inventory drivers. First of all, inventory values are more unpredictable since they depend on price-volatile raw materials. The adequate size of inventory is critical for stable operations, to ensure delivery capability, to reflect campaign cycles and planned production shutdowns, or to hedge the risk of volatile raw material and sales prices. Companies that operate globally need to manage inventories in multi-site and multi-level networks, including inventories shipped by sea or other means of transport (Schulz et al. 2006).

Our specific chemical industry case study involves a global commodity business that produces standard polymers. Inventory management is an integral part of the overall value chain management concept of the business and covers strategic, tactical and operations aspects.

- The company determined their stock-keeping strategy, including the inventory boundaries required to operate and compete in different global markets. Specifically, in Asia, a dedicated concept was required because a decision needed to be made among local stock in several countries including China, Japan, Korea or a central hub, for example, Singapore.

- Tactically, inventory volume and values were managed in the planning process and integrated with sales, transportation, production and procurement volume and value planning. Inventory volumes anticipated shutdowns and supplier forecasts; inventory values were planned to account for raw material price forecasts and planned exchange rates that might change over the course of a fiscal year.

- In terms of operations, inventory was managed on a daily basis and allocated to customer orders and deliveries; in global operations, specifics to be considered included container sizes and adherence to container ship schedules.

In the case of this specific company, value chain performance management focused primarily on monitoring inventory volumes and values to ensure delivery capability but also to keep working capital costs low. Given the volatility of prices and volumes in a business that deals with commodities, the company was frequently challenged by high fluctuation in their inventory values and volumes, which were either too high if planned sales could not be realized, or too low to catch up with growing demand. Both situations would have a negative impact on the stability of the value chain and profitability overall. The company therefore defined global inventory ranges and established a monthly inventory monitoring process using monitoring gates and event management procedures.

A characteristic KPI is the inventory range measuring the actual inventory value divided by the actual sales value in the current month. Inventory ranges should be in a certain bandwidth (for example, between 40 days and 60 days), depending on the company's value chain structure and inventory drivers (Schulz et al. 2006).

Inventory monitoring gates during the month need to be defined. In this case, two monitoring gates were determined for the middle and end of the month and one review gate in the next month. A clear event management process was defined in the event of deviations between the measured inventory range compared to the tolerated bandwidth. In this case, a structured event management approach needed to take place. As owner of the process, the supply chain management team, together with sales and production representatives, needed to begin a three-step process. First, internal resolution options were checked by supply chain management, production and sales; for example, the team identified additional sales opportunities or opportunities to cut sales in the event of excess demand. After two days without a solution, the team contacted customers and suppliers to discuss potential changes in the volumes of products delivered and supplied. If neither of these actions helped the situation, the team reported the situation to top management. Top management must be informed about any negative deviation in key reporting indicators because several million Euros of additional capital can be the consequence (Fig. 6).

Introducing this pragmatic inventory monitoring and event management helped the company to stabilize inventory volumes and values globally and respond proactively and more effectively to value chain and market changes. Monitoring also helped to prevent destabilization of the value chain. The process provided opportunities to apply automated monitoring and event management tools and decision support. However, given that investment in working capital related to inventories of bulk chemicals could easily reach several million Euros, automated decision making was unlikely. Management should always be involved in the situation and be responsible for making significant business decisions.

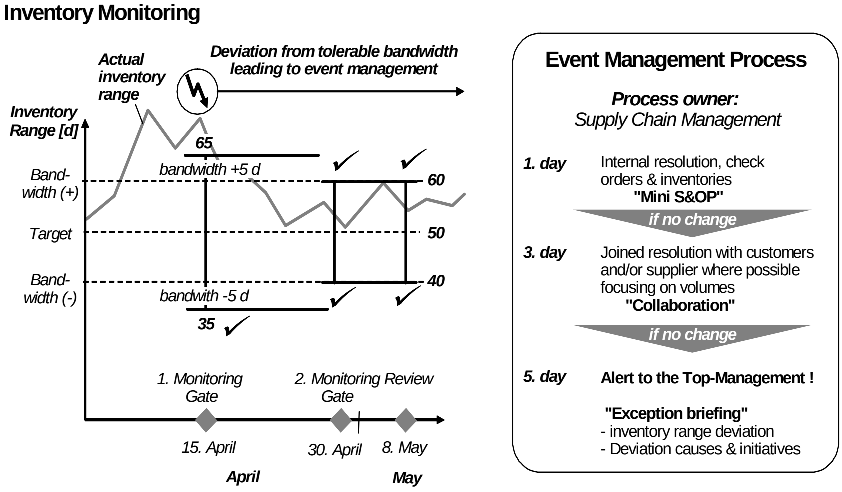

Fig. 6. Inventory monitoring in the chemical industry

IT Based Shelf Life Management in the Fresh Food Industry

In Germany, the food processing industry is one of the main economic sectors, reaching an approximate turnover of € 100 billion Euros. Nearly 50 percent of this amount is contributed by the fresh food industry, which includes fresh and processed meat, dairy, fish, fruit, vegetables and bakery products. In general, value chain management of fresh food production is a challenging task. Even more challenging are factors such as the high variability of raw materials, the quality of intermediate and final products, fluctuating prices and variable processing times and yields. One aspect is the most difficult of all to handle: shelf life, which is the most important factor to consider in planning fresh food production. The definition of shelf life is the period of time in which a food product will remain safe, be certain to retain the desired sensory, chemical, physical, and microbiological characteristics, and comply with any label declaration of nutritional data (Kilcast a. Subramanian 2000). In addition to time, product shelf life depends on appropriate temperature control during the entire process and across the chain.

In the fresh food industry, a typical value chain includes the farmers, producers, distributors and retailers. There are two types of industrial processors. The first transforms natural materials into intermediate products. An example is an abattoir in the meat industry, which delivers some of its products, such as fresh meat, directly to customers through wholesalers and retailers. The abattoir may also supply products to the processor of consumer products (e.g., sausage or ham producers). In other fresh food value chains such as dairy, only one type of producer is part of the value chain.

Within the past few years, the fresh food value chain has been subject to significant changes. Internationalization is an important factor, as many companies have quit their traditional orientation to domestic markets and become increasingly global. Another clear trend is toward consolidation across all stages of the fresh food industry value chain, from farmers to processors to retailers. The rise of private labels has also affected the value chain. These private labels, launched as the brands of individual retailers, are achieving remarkable market share and retail margins.

Private labels are closely related to another specific retail channel, the discount, which is characterized by limited assortments, concentration on only a few suppliers and price leadership in most categories. These various changes in the value chain have influenced the balance of power between retailers and manufacturers in the food industry. Retailers are now in a position to demand higher value chain performance from manufacturers, resulting in improved lead times and reduced average size of retail orders.

All of these developments lead to growing pressure on cost margins for all participants in the fresh food value chain. Many items yield very low margins. Today, food prices in the Western world are probably the lowest they have been in relation to average salary. Therefore, effective management of the value chain will be a decisive factor in the future success of all participants.

In the fresh food industry, effective management of the value chain is crucial and includes tight shelf life monitoring and active shelf life management, which both affect cost and revenue. With respect to costs, the main benefits of value chain management include reduced waste of raw materials and intermediate and final products, as well as optimized set-up and cleaning costs. The effects on the revenue side are even more important, as consumers usually tend to buy products that have the longest possible shelf life.

In addition, retailers demand that manufacturers deliver products that are as fresh as possible and, in general, refuse products if a third of their shelf life has already has passed.

Longer shelf life is a pivotal competitive advantage for fresh food producers. Therefore, value chain management systems provide significant support for the planning process. Driven by developments in supply chain management and information technology, value chain management systems focus on material restrictions and capacity constraints at the same time. This is an important differentiating factor, since the widely-used and implemented Enterprise Resource Planning (ERP) systems address these topics only successively. The entire value chain network could be optimized by integrating several production sites, distribution centers, suppliers and customers into a single planning model. Surprisingly, in the fresh food industry, the number of value chain management systems being implemented has not increased significantly. The leading providers report rather low numbers but no considerable implementation in these industries.

As this detailed analysis has revealed, shelf life management supports these systems with several existing basic functions. Available data fields provide information about total product shelf life, minimum maturation time and the customer's minimum requirement for shelf life. Because shelf life is not only relevant for final products but also for raw materials and intermediate products, value chain system production scheduling modules usually report shelf life daily and continuously (Luetke-Entrup 2005). In addition, various alerts are scheduled when shelf life exceeds product maturation times or minimum customer requirements.

However, at present, value chain management systems are not technically mature. Some important shelf life functions related to fresh food production are currently available only in selected systems or not at all. Examples are missing data parameters on minimum and maximum maturation times or blocking and quarantine times; missing support of shelf life propagation (when the shelf life of a product depends on the shelf life of the raw materials, as in the processing of fruits and vegetables); or an incentive to optimize the freshness of the products. These technical problems must be solved.

Management of the fresh food value chain is a compound challenge, with shelf life remaining an essential issue. Organization of the entire value chain could be considerably improved by management systems that bring more profit to the entire chain, including manufacturers, retailers and consumers. Without management systems that provide optimized coverage of shelf life, a pivotal precondition for success is missing.

Assortment Management in the Retail Industry

Value chain management in the retail industry provides significant opportunities for improving efficiency and effectiveness in the core competence of the retailer: managing the store assortment. Using modern merchandise management systems, retailers can optimize their value chain on the strategic, tactical and operational levels. Value chain management and performance concepts, as well as skillfully implemented merchandise management systems, need to take into consideration the following retail-specific challenges and requirements:

- Retailers' assortment management is challenged by increasing uncertainty in consumer demand that causes lengthy response times for stock replenishment and order fulfillment. Because of these long response times, the outlet's safety-stock increases. At the other end of the value chain, suppliers' safety stock also rises because of poor communication about changes in demand. Additional problems are a high number of reconsignments and internal transfers of items involving too many extra trucks between distribution centers and stores.

- The order-to-cash cycle is often too long, driven by as-is order scheduling. Retailers without an effective merchandise management system also have no chance of quickly tracking items linked to an order because the status of orders is not transparent.

- Another well-known problem is a potential stock-out before any alert or corrective action can take place. And lastly, unnecessary order schedule changes can consume time and cost.

- From the retailer's perspective, it is often not possible to monitor the supplier's performance and their contribution to profitable operations.

Modern value chain management concepts and merchandise management systems are automating major value chain management and monitoring processes on the strategic, tactical and operative levels and provide valuable information for strategic activities.

On the strategic level, an assortment and portfolio management system includes the analysis of items by categories and also keeps track of individual stock-keeping units (SKUs) detailed by sales and performance. This key information optimizes strategy related to market position, assortment, pricing, sales format, distribution and suppliers. Items with high turnaround rates, season-relevant items and the management of fillers are part of the issues that require strategic management. Events such as permanent delays and poor quality of merchandise from Asian suppliers can result in the selection of a local supplier, especially for valuable or luxury goods. Having a well-defined strategy with the related KPIs is input for the tactical planning of the assortment volumes and value.

Tactical activities for retailers include planning order volumes and values, especially for goods with long order times. In this case, the lead time specifics of global value chain networks need to be considered; an example is the next seasonal textile collection which is produced in Far East and has a production and shipment duration of about three months. Planning order volumes and exact timing are important to meeting season-dependent customer demand. Modern value chain management processes are driven by category managers who can determine and manage volume flows based on historical and anticipated market data; in the case of textiles, they must also consider product details such as colors, sizes and quality. Tactical value chain monitoring of planned volumes and incoming deliveries is a key task in this context.

Pricing and promotion management are additional tactical sales activities impacting volumes and values in the entire value chain. By tracking sales rates at different price levels through the year, reliable forecasts can be made to achieve optimal prices. Price management is an important aspect of promotions, which change almost weekly.

Promotion planning begins nearly one year in advance and is updated during the year. Constant monitoring of different events is required to launch the best weekly promotion. For example, current bad publicity about a meat product must be reflected in a promotion and lead to changed orders, otherwise tons of meat will go unsold. Other events to be monitored are the unavailability or shortage of items expected to be promoted, or a significant change in weather such as a heat wave that brings increased demand for beverages, ice cream and barbecue-related products. Depending on the status of printing and distribution of promotional materials, different responses are necessary. If there is still time to make a change, one potential response is to substitute the planed product by an alternative one. If an advertisement is already published, all stores must be filled with minimal amounts and additional orders to the supplier or other retailers need to be organized. The worst case is an early stock-out, which can be handled by offering a substitute product for the same price in the stores.

On the level of operations, retailers have recently put their highest emphasis on developing better processes and systems for automating operations. Nowadays, sales representatives in outlets can order directly online at the shelves instead of writing lists and calling suppliers. In the past, allocation of goods was made on paper in the distribution centers; today Pick-by-Voice systems facilitate item handling and also improve quality and reduce processing time. Online systems monitor major operational activities along the value chain and take corrective actions and provide alerts depending on the values of the recognized events. Automated solutions recognize defined, repeated events that cause trouble in the value chain and corrective action can be taken. Table 1 shows a number of typical events that can be foreseen and the automatic actions that can be taken to correct them.

Table 1. Events and actions in retail assortment management

Events (Selection)	Actions (Selection)
Missing item in an order	If possible, reorder the item for the next delivery.
Wrong delivery of an order	Initiate a reshipment of goods that are not listed or not needed.
Delay in delivery	Provide an alert and prepare an alternative order for approval.
Stock at the distribution center is below the level of orders	Regroup orders to match as many as possible. Initiate new orders.

In summary, value chain management, including performance management and monitoring of assortment-related topics, are of key importance to retailers. Corrective tasks can be found on strategic, tactical and operative levels.

Automated monitoring and event management are most relevant on the operative level, while transparency and decision support, such as support from the merchandise management system, are required on the tactical and strategic levels.

Summary

Performance management is an integral part of a value chain management framework. It must match strategic, tactical and operative process levels as well as interface with IT and organization management. Performance management itself must distinguish strategic and tactical cockpits based on KPIs for top management. Operative monitoring and event management must steer daily transactions. IT and automated event management solutions are more suitable for application on the operative level, while tactical and strategic performance management require human interaction and decision making. These three industry examples show that each industry faces unique requirements, performance management issues and items to be managed. Inventory management is a key issue for high capital-intensive bulk chemicals; shelf life is a specific concern in the fresh food industry; and assortment management is crucial in retail, given the high complexity and different turnaround rates of selections in the stores. With these three industries as illustrations, scientists and practitioners should take industry-specific issues into consideration as they develop management concepts and software solutions.

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Supply Chain Event Management in the Retail Sector – Three Steps to Success

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Introduction

Companies such as Metro and Wal-Mart have long recognized the strategic advantages of digital supply chains. Their response has been straightforward: Start preparing now, even though the technical requirements for using radio-frequency identification (RFID) across the entire logistics chain lie some way in the future. Other retailers can learn from their example. Getting their basic processes in shape now will ease the transition to fully automatic supply chain event management (SCEM) later on.

In this article we present a three-stage model that companies can use to optimize their logistics chain, step by step. We show that efficiency gains can, in fact, kick in earlier than expected – not when the new technology comes along, but already during the earlier stages of integrating and stabilizing basic processes. Finally, we reveal how a transformation roadmap can help companies to plan and manage their realignment to supply chain event management with a maximum of ease and efficiency.

The Digital Supply Chain – A Vision for the Future

For most of us, supply chain event management still lies somewhere down the road. However, companies must start getting the basics right today if they want to gain maximum benefit from the event-driven logistics chains of the future. So what exactly is supply chain event management? In a nutshell, it is a system in which automated, self-steering logistics chains do away with the need for human intervention entirely, unless something irregular or unusual happens.

In supply chain event management, the flow of goods and information is managed by computer. The products themselves bear a clear mark of identification, such as an RFID tag, and are tracked automatically as they pass along the logistics chain.

Supply chain event management makes logistics chains more reliable. It raises both efficiency and transparency. For this to be possible there must be a high level of information exchange between the different partners in the logistics process. This means powerful information systems, networking the different parties and providing data when and where it is needed. The data must also be of high quality. Objects need to be identified correctly as they pass through the logistics process. To this end, the time at which shipments pass different points along the logistics chain – e.g. goods-in and goods-out in the warehouse, cargo handling points – is recorded and sent back to the system.

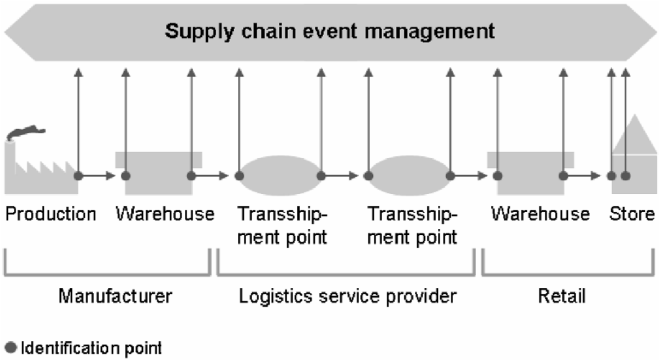

Fig. 1. Supply chain event management in consumer goods and retail

This means that all parties in the logistics chain now have access to high-quality, up-to-the-minute shipping and stock information (Fig. 1). For instance, if a container delivery from Asia is held up at its port of entry for longer than a specific tolerance threshold, this information goes immediately to the control system and is communicated to the company awaiting delivery. The system then automatically checks the days of supply in the central warehouse and in the retail stores themselves. If there is sufficient stock, all is well and good. However, if the delay in delivery puts availability in the stores at risk, the system sounds the alarm. It then generates a solution for speeding up the logistics process that must be manually approved by the Supply Chain Manager.

The system involves recording a large amount of data at a significant number of points along the supply chain. This gives the different partners involved great transparency over the quality of the logistics process and any potential weak links. Current systems often lack such transparency. For example, companies are frequently in the dark as to the quality of service provided by their suppliers.

They find themselves wondering whether a missed deadline was due to delays in production, the shipper failing to meet agreed transportation times, or perhaps incorrect delivery times in their own order systems. This lack of transparency can make them unsure what action they should take to remedy the situation.

In complex supply chains, problems can occur at all levels. The causes are manifold. However, the upshot is always the same: The overall quality of service drops. Often the underlying problem is not in the process – a delay in goods being picked for shipping or a hold-up in transportation, for example. Rather it is the poor quality of the logistics data itself. For instance, a situation may arise in which orders are recorded incorrectly because the electronic code used by the retailer gives a different article number from that in the manufacturer's master data. Or stocks may be recorded incorrectly because the wrong article number appears on the products. Problems such as these can cause even the most robust logistics processes to wobble. And that means a drop in service level plus a whole heap of extra work correcting and compensating for mistakes all the way along the logistics chain – extra work that does not deliver one cent of extra value.

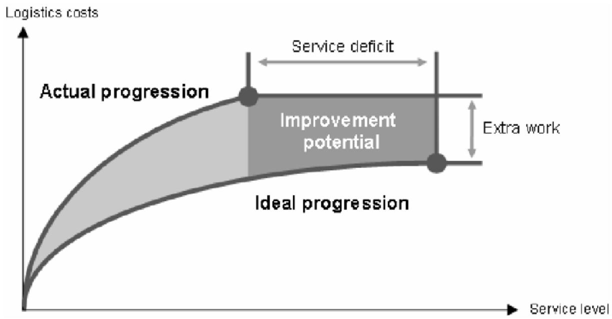

Fig. 2. Impact of service level deficits

Problems with the service level (Fig. 2) have a nasty habit of multiplying as they pass down the logistics chain. Information regarding product availability may be incomplete at the point of sale, despite a company's best efforts to correct hiccups in the logistics process. This can have serious consequences. Consumer research shows that in nine percent of cases, when shoppers don't find the articles they want in the place they expect to find them, they decide to buy nothing at all. Not even an alternative product. This nine percent of cases represent some four billion euros in lost sales. And that's probably just the tip of the iceberg. When stores fail to come up with the goods time after time, even long-standing customers begin to shift their loyalties. For retailers, losing an established customer could mean – in the case of a family, for example – a drop in weekly sales of around EUR 150. Over a period of 20 years, that's EUR 150,000 in lost sales.

Three Steps to Successful Implementation

The math is clear. Retailers can make enormous gains by improving their logistics processes. How? By starting down the road toward supply chain event management. Supply chain event management involves event-driven logistics chains that are supported by information networks. These are also known as digital supply chains, as the standard procedures are controlled by computer and the Supply Chain Manager only intervenes in specific situations. In many cases, the technological requirements for end-to-end supply chain event management – such as the widespread use of RFID tags – are not yet in place. However, companies can tap into many of the benefits already, by taking the necessary organizational and technical steps to prepare themselves for the future.

Making preparations now will ensure that companies are ready to enter the age of digital supply chains when it finally arrives. It will also give them a competitive advantage over companies that are less quick off the mark. Harmonizing data and standardizing processes is not something that can be copied wholesale from other companies later on and implemented overnight. Companies need to set the wheels in motion now. Below, we show how companies can go about this. The recommendations are aimed primarily at retailers; however, they are equally relevant to other participants in logistics processes.

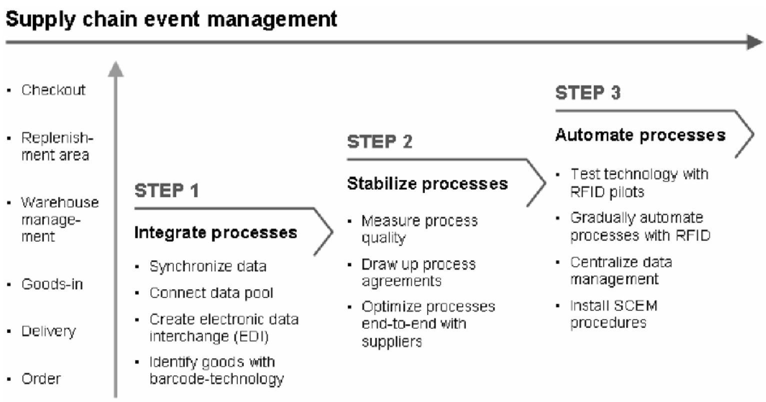

Fig. 3. Three-step approach

We recommend a three-stage model for implementing supply chain event management. Using this three-stage model (Fig. 3), companies can optimize their logistics chain step by step. Step 1 is creating the necessary conditions for supplier integration. It involves synchronizing the database and creating an electronic data interchange network with suppliers. At this stage, companies should also introduce a system of identification using barcodes. In Step 2, companies and suppliers work together to make their processes robust. This means introducing a framework of KPIs and supplier scorecards for measuring the quality of the flow of goods and information. This makes the processes increasingly stable over time. Finally, in Step 3, the company runs a series of RFID pilot applications, automating each of the logistics processes in turn, from goods-in right up to the sales-floor. Below, we discuss each of the three stages in detail.

Step 1: Integrate

The starting-point for continuously integrating and optimizing processes with suppliers is to harmonize the article master data. The master data has to be correct for the exchange of electronic outputs to proceed smoothly. This also ensures that merchandise is identified correctly as it proceeds along the logistics chain. The key piece of information here is the European Article Number, or EAN, which is the product's identification mark. The EAN-13 is made up of 13 numerals: the manufacturer's Global Location Number (composed of the three-digit EAN country code followed by the four-digit manufacturer code), the five-digit product code, and a check digit. The EAN-13 appears as a barcode on all articles and allows them to be identified by scanners during logistics processes and at the checkout. At the same time, the EAN-13 functions as a reference number in all communication with the supplier, e.g. orders, dispatch advices and invoices.

Today, the information available to suppliers is often out of synch with that available to the retailer. This creates delays in the logistics process. For instance, delays may occur in suppliers processing orders because the retailer has given the wrong EAN-13. Or items are delivered to the retailer with a different EAN-13 and so cannot be recorded to stock or put out on the shelves. This leads to products being unavailable and hence lost revenues for the retailer. Sometimes the fact that an article has an illegible EAN-13 barcode goes unnoticed right up until it reaches the checkout. This slows down the checkout process and impacts negatively on customer satisfaction. Such problems create considerable extra work for both retailers and suppliers.

The EAN-13 barcode appears on the product itself. For the logistics processes in the warehouse and the stores, another EAN-13 barcode is needed on the transport packaging (i.e. the covering box). This enables operatives at goods-in to check deliveries on pallets quickly using a scanner. Putting an EAN-13 barcode on the transport packaging is the first step toward automating the entire process with RFID tags. The EAN-13 barcode on the transportation packaging also often serves as the basis for processing orders with suppliers. To ensure that the data available to suppliers is synchronized (and consistent) with that available to retailers, companies need an electronic system for managing master data. These days, new product listings are common and old products are subject to alteration. Electronic updating means that the necessary adjustments can be made to the database efficiently. One solution is for retailer and suppliers to use an extranet-based system for managing master data. This automatically passes master data between the systems used by the suppliers and the retailer's merchandise management system. Alternatively, the various parties can be connected up to a centrally-managed pool of master data, such as the multilateral SINFOS portal developed by GS1 (Fig. 4). This system compares international master data using the global GS1 standard; it is currently used by some 2,500 companies in more than ten countries. GS1 Germany is part of the worldwide GS1 organization, which aims to implement global standards in business processes in the consumer goods industry and retail.

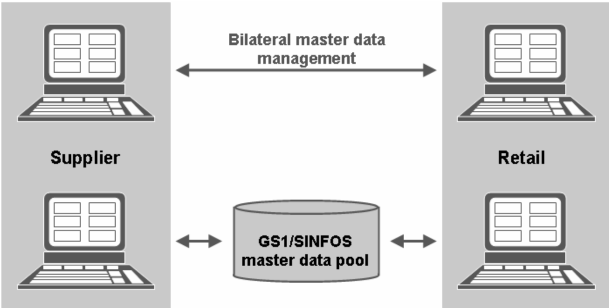

Fig. 4. Master data management

To ensure that any errors are picked up early on, retailers should create check points as far up the logistics chain as possible. For instance, checking the EAN-13 barcode at goods-in in the central warehouse will reveal if it is scannable and if the article number is recorded in the merchandise management systems. If it isn't, the system can automatically trigger an updating process, avoiding later problems at store level.

The next step toward integrating processes is to set up a closed electronic data interchange (EDI) network between the retailer and the suppliers (Fig. 5). With EDI, standard output types in business processes between retail and industry – such as orders, dispatch advices and invoices – are processed electronically. Transactions are dealt with quickly and efficiently and there is close synchronization between the different parties' systems.

The two key output types in logistics processing are orders (ORDERS) and dispatch advices (DESADV). These are also the key output types for implementing supply chain event management. Dispatch advices are the electronic codes that suppliers use to give retailers an electronic picture of the goods shipped. They contain a unique reference number relating to the order. The dispatch advice is fed into the merchandise management system and allows the articles to be recorded to stock the moment they arrive at goods-in in the warehouse, unless closer inspection is required.

Electronic dispatch advices can speed up goods-in processes significantly. Combining them with spot checks substantially reduces the amount of work involved in checking goods-in; products also reach the shelves much more quickly. Naturally, this only works properly if the electronic dispatch advice matches exactly the goods delivered. Once again, the quality of the data is critical.

Connecting the flow of information with the flow of goods – and synchronizing the two – is a key feature of supply chain event management. The first step is to use barcode technology to identify items at various stages in the logistics process. This puts the technological requirements in place for the switch to RFID later on. The basic principle of recognizing objects by means of a coded identification number is the same in both systems as far as data-handling is concerned.

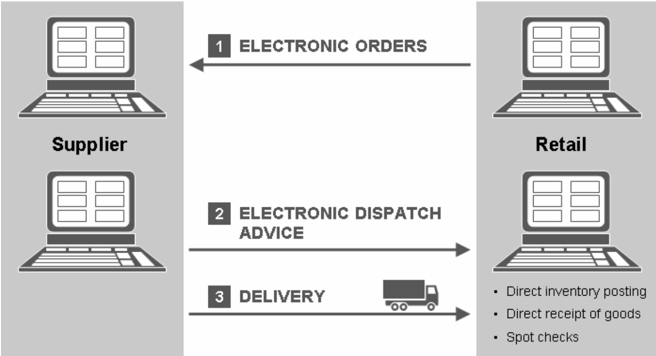

Fig. 5. EDI data links

The first level of identification in the flow of goods is that of the transport loading unit. These loading units are generally pallets that are marked with a unique number. In a barcode-based system, the pallet is labeled with a barcode that functions as its unique reference number – the serial shipping container code (SSCC) – which can then be read by a barcode scanner. In an RFID-based processing system, the SSCC is encrypted as an Electronic Product Code (EPC) on an RFID tag and can be read by an RFID reader. In both cases, the system records the shipping data in the electronic dispatch advice in the form of a unique SSCC. The contents of the pallet can be identified by reading the number, and recorded directly in the merchandise management system. One important difference between barcode- and RFID-based systems is that in a barcode-based system the scanner has to be pointing directly at the barcode, whereas in an RFID-based system the tag does not have to be in the line of sight of the reader.

In fact, implementing supply chain event management is not primarily a question of technology. It is much more about establishing robust business processes. Crucially, companies must first achieve maturity and stability in their processes for managing master data, electronic information exchange and barcode identification. Only then should they begin step-by-step migration to RFID, via a series of pilot projects. Current pilot projects on RFID implementation have shown the importance of dealing with any weaknesses in the basic processes between supplier and retailer before attempting migration. If companies try to skip this step, the real benefits of RFID ultimately fail to materialize.

As discussed, the first step is to mark loading units with SSCC barcodes, and mark the transport packaging units on the loading units with EAN-13 barcodes. SSCC identification also helps to rationalize goods-in and warehouse management processes. The supplier marks the pallet for shipping with an SSCC and this weds it to the articles on it. This information is communicated to the person receiving the goods via the electronic dispatch advice. When the truck arrives at goods-in, the loading units in the shipment can be checked immediately by scanning. This is more reliable than entering dispatch advices directly into the merchandise management system, as incorrect shipments are unavoidable. SSCC also make it easier to carry out spot checks: Operatives can simply call up the article details relating to the pallet in question from the electronic dispatch advice, rather than checking through the entire dispatch advice. Operatives should also be able to scan in the EAN-13 barcodes on the boxes or individual articles. Using SSCCs for identification purposes also allows companies to introduce a warehouse management system, speeding up the process of moving products from the backstore to the salesfloor.

Besides streamlining the goods-in and warehouse management processes, companies can use SSCCs to track loading units right along the logistics chain. The time and place of each electronic identification can be recorded in a central database and used to monitor and control the flow of goods. This is particularly useful for promotional items that have to be available in the store when the promotion begins. Comparing individual time stamps at different identification points with the timetable drawn up at the planning stage will reveal any delays and enable the retailer to take corrective action (e.g. Fig. 6). This ensures that the goods reach the store when they are needed.

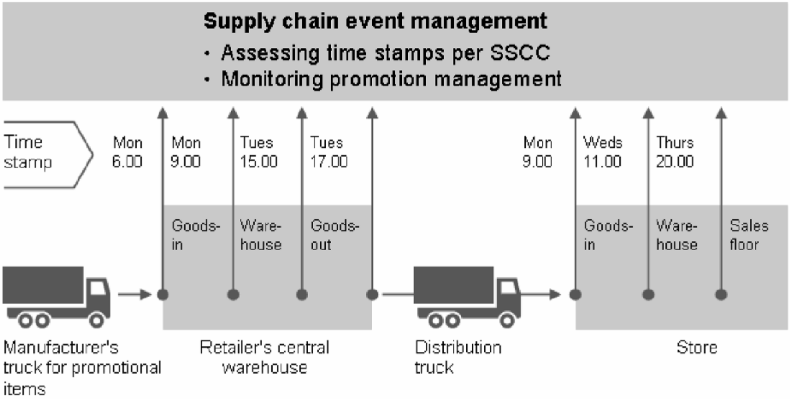

Fig. 6. Promotion management

Step 2: Stabilize

The next step is to stabilize the business processes involved in the logistics chain. Supply chain event management requires processes that are highly stable. The flow of goods and information needs to be closely synchronized in all steps of the process. The environment itself is far from static, so the process needs to be highly robust for automated process management to be ultimately possible. Any causes of instability within existing business processes must therefore be picked up and dealt with early on.

A good way to achieve transparency over process deficits and their causes is to use a system of key performance indicators (KPIs). KPIs take relevant data from the flow of goods and information and transform it into supply chain indicators.

Companies can then draw up scorecards – one for the company itself and one for suppliers – covering the relevant process indicators. The scorecards give the target levels against which improvements in quality are to be measured. On this basis, companies can draw up process agreements with their suppliers. Such agreements may contain targets for introducing electronic business processes – getting connected to a pool of master data, creating an EDI network, or such like – as well as quality targets for the processes themselves.

The system of KPIs should cover three key areas. Firstly, it should define indicators for measuring the quality of master data and its electronic management. Secondly, it should evaluate the quality of the electronic data exchange for the main output types. And thirdly, it should set the indicators for measuring the quality of the physical deliveries, particularly as regards meeting deadlines and volume requirements. Figure 7 gives some examples of possible indicators.

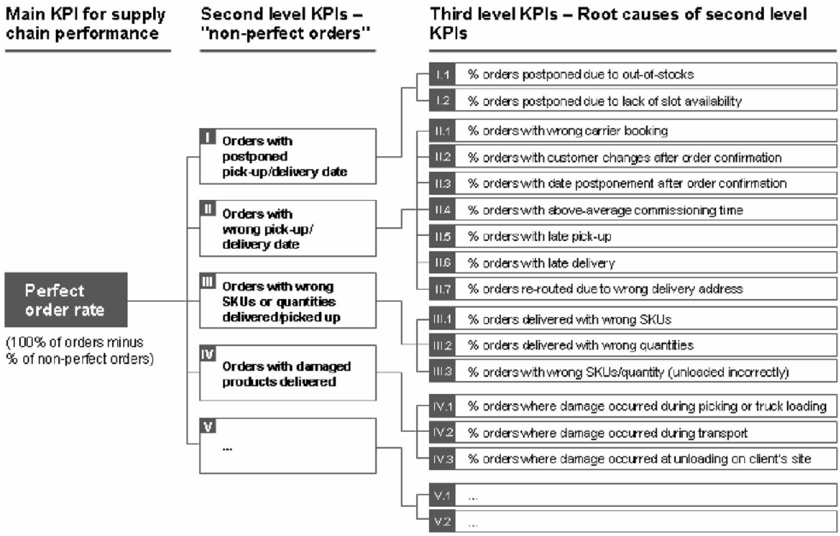

Fig. 7. KPI system

The system of KPIs should be constructed in such a way that the indicators can be generated automatically from the data in the system. Doing this manually would be too time-consuming given the number of different suppliers and transactions. It is also important to ensure that the data is consistent so that the reasons for process deficits can be identified beyond any doubt. EDI, merchandise management data and logistics data from the different systems should then be brought together using a data warehouse application. This allows the company to monitor process quality using prioritization, selection and filter criteria. Relevant indicators (and the option to view the data behind them) should be accessible to all parties involved in the logistics process, via an intranet or extranet system. In addition, the company's internal and supplier scorecards should give both current and target values. It is also essential to define clear responsibilities for the different functions involved in the business processes.

Process agreements are an effective instrument for involving suppliers in the process of optimizing logistics. Process agreements should cover all the relevant requirements for flows of goods and information from the point of view of the retailer. The company should agree with its suppliers what electronic output types they have to implement, and by when. The process agreements should also include targets from the supplier scorecard – such as attaining a certain quality standard for electronic dispatch advices or meeting predefined service levels. This should be backed up with appropriate sanctions if the supplier fails to meets the targets. In this way, a system of KPIs, scorecards and process agreements can set a process of continuous improvement in motion (Fig. 8).

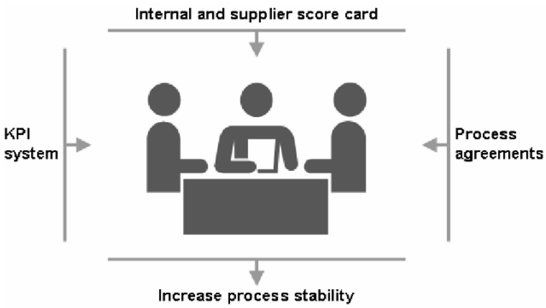

Fig. 8. Continuous improvement concept

By following these instructions, everyone involved in the process can gain transparency over the causes of errors and their ramifications. Given the complexity of EDI networks, companies will need to set up interdisciplinary project teams bringing together representatives of Purchasing, IT, Supply Chain Management and the suppliers. These teams should agree joint actions aimed at increasing process stability. The causes of errors can take many different forms and identifying them is not always straightforward. For instance, repeated delays in electronic dispatch advices being entered at the stores could be due to faulty processing by the supplier. However, it could also be due to the retailer processing the dispatch advice sequentially, leading to delays in the information becoming available. Or the problem might lie with the order process itself: often, the supplier's sales reps take the orders and no electronic order code is generated. As a result, no order number appears on the electronic dispatch advice as a reference and so the data is rejected. Integrating business processes electronically and achieving a high level of process stability has two effects. Firstly, the processes themselves become faster and better synchronized. Secondly – and more importantly – improving logistics process stability raises the efficiency level. Today, errors and delays in processing generate a large amount of extra work for companies. Sorting out operational problems is time-consuming and brings no additional value. Companies should first release the potential trapped in this area, before moving on to automating their processes.

Step 3: Automate

The aim of supply chain event management is to achieve fully automated logistics processes that are controlled by computer. Processes can be steered automatically using to a workflow principle; operatives only intervene in the flow of goods under exceptional circumstances. For supply chain event management to work, the system must be able to automatically identify objects and generate appropriate logistics commands. In other words, process automation occurs on two levels: in object identification (e.g., using RFID technology) and in process management. Large retailing groups such as Metro and Wal-Mart aim to ultimately achieve fully automated logistics processes; their pursuit of this goal is driving the technology ahead.

The first stage in automating retail business processes is to automatically identify merchandise at goods-in using RFID technology. An RFID tag programmed with the serial shipping container code is attached to each pallet. The tags are then read by an RFID reader and entered into the merchandise management system; the tag does not have to be in the line of sight of the reader (see e.g. Fig. 9). The SSCC is transmitted in the form of an electronic product code (EPC). EPCs are a standard number system used around the globe in RFID-based business processes. The merchandise management system compares the EPC with the number on the dispatch advice provided by the supplier via EDI. If they match, the loading unit is marked as having been successfully identified. The operative receives a visual signal at the goods-in gate and can immediately store the pallet or take it to the sales-floor. This speeds up processes at goods-in considerably, replacing paper-based activities with automatic processes.

Automatic identification not only makes processes faster, but also of higher quality and more stable. Stock data is updated as soon as the shipment is physically received. If items are out of stock, the process of moving them to the sales-floor is triggered automatically. This, in turn, improves product availability. At the same time, recording items to stock using RFID technology also improves the quality of merchandise planning. In traditional goods-in processes, there is often a delay of several hours before items are recorded to stock; stocktaking and checking processes are slow and laborious. With RFID technology, shipments can be recorded and stock data updated instantly. With these improvements, companies only need to check individual products more closely when the need arises.

By applying these methods, retailers can optimize all their operating processes, starting with their goods-in processes.

The ultimate goal is to automate the entire process chain, from goods-in at the warehouse to checkout in the stores (Fig. 10). However, the extent to which automation is feasible depends on the level of RFID identification they choose to employ. In addition to marking pallets with tags, case-tagging and item-tagging are also possible. The more levels of identification companies use in their logistics processes, the greater the extent of automation they can achieve in their customer-related processes.

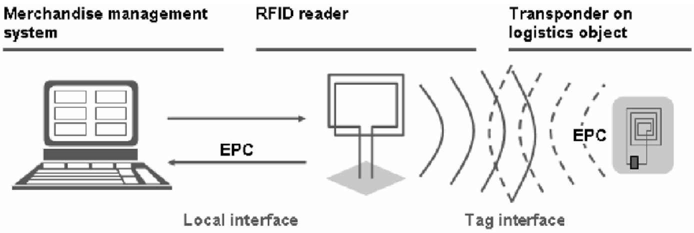

Fig. 9. RFID identification

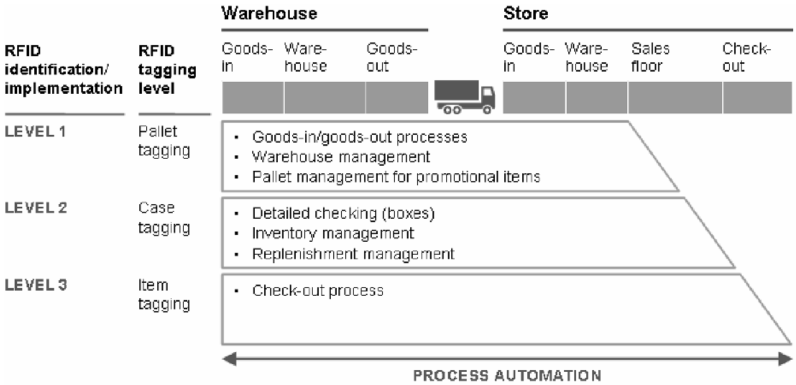

Fig. 10. RFID process automation

On the sales-floor, the main logistics task is moving boxes and individual items around. Here, the two areas with greatest potential are automatic replenishment management (improving the availability of items on the shelves) and automating the checkout process. Automatic replenishment management and smart shelves allow retailers to control stock levels both in the warehouse and on the sales-floor by computer. The moment a customer takes a product with an RFID tag off the shelf, stock is automatically reduced. When stock falls below a specific threshold, the system automatically sends out a replenishment order and an operative can refill the shelf with the required item. This improves the presence of goods in the store. The second area – automating the checkout process – creates extra efficiency and improves customer satisfaction. It effectively consigns long lines at the checkout to history. Customers do not even have to remove the items from the shopping cart: They simply push the cart past an RFID reader and its contents are read automatically. The customer then pays directly at a POS terminal.

A number of technical and financial conditions still need to be met before RFID processes can be implemented in all areas of the sales-floor. For automatic replenishment and checkout processes to work properly, pretty much 100% of boxes and individual items must be identified correctly by the RFID system. This is particularly important for bulk reading. Products are often piled up next to each other on the shelf or in shopping carts. Neighboring products can effectively block the signal coming from the RFID tags. This is particularly common for products with a high fluid or metal content.

RFID technology has not yet overcome this problem and so identification rates are still too low. In addition, RFID tags are too expensive for tagging at the level of individual products to be economically viable. Smart shelves and RFID readers located on the sales-floor and at checkout are also prohibitively expensive.

Companies must automate both identification and information processes for successful supply chain event management. RFID identification of logistics objects produces substantial information along the entire process chain. Since fast and closely synchronized availability of this information is necessary, central data storage concepts are being pursued. These concepts involve the individual partners in the supply chain feeding their information into a central database. The database is then used to supply the company's supply chain event management system. For example, ECP Global, a global standardization organization for RFID applications, is currently developing concepts for central databases. It still needs to be decided whether only status information on logistic objects should be stored centrally or if transaction data (e.g. orders, delivery notifications, and invoices) should also be kept centrally. Transaction data however should be kept centrally to fully synchronize data and achieve data consistency. This ensures that all systems in the supply chain have the same level of current information. In turn, this allows the supply chain event management system to quickly react to disturbances in the process chain and take corrective action.

Start the Transformation Early

Implementing supply chain event management requires radical change for companies in the areas of organization and technology. Ultimately, it means a revolution in how they operate. Companies such as Metro and Wal-Mart have recognized the potential of such changes. They have understood that bringing their supply chains into the digital age gives them a strategic advantage over their competitors. Today, these companies are driving RFID technology ahead. And they are already enjoying the fruit of increased process efficiency. This is something that other players will find it hard – if not impossible – to copy overnight. The efforts already made by Metro and Wal-Mart to integrate and stabilize their processes have largely eliminated non-value-creating activities in their logistics chain. They stand to gain not only in terms of efficiency when the new technology arrives, but also through the improvements in their organization and processes today.

Other companies need to wake up and smell the coffee. Many are currently standing on the sidelines, waiting to see which way the technological wind will blow. But this is a risky position to take when it comes to ensuring future competitiveness. Rather than waiting to see what the future will bring, companies should be proactively transforming themselves, putting the basic requirements for supply chain event management in place today.

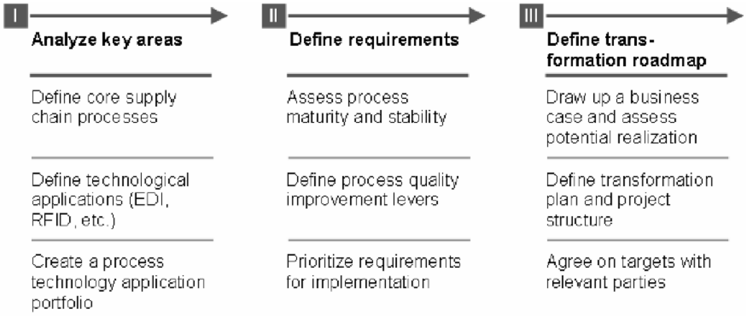

Fig. 11. Transformation roadmap

A transformation roadmap can be a useful tool for this (Fig. 11). It defines the strategic framework for realigning business processes, specifies the key areas where supply chain event management is to be applied, evaluates the quality of current processes and uses this as a basis for drawing up an implementation plan. The implementation plan then acts as a step-by-step guideline for optimizing processes and introducing the new technology.

The three steps of integrating, stabilizing, and automating processes should run in parallel or partially overlap in the transformation roadmap. Meeting the technological requirements must help shape the processes early on. For example, the technological requirements for moving to RFID-based processing must be taken into account when optimizing the system for managing master data or deciding on the structure of the codes for EDI-based processing. Equally, as soon as basic EDI output types are introduced and stable, pilot RFID applications should be launched. This will show companies what still needs to be done in terms of shaping processes and improving quality. Suppliers and retailers can then bring their basic processes up to speed, at the same time as developing RFID technology.

This parallel approach – optimizing basic processes at the same time as introducing new technology in pilot applications – is the key to successfully implementing supply chain event management. If companies fail to meet the requirements for their processes first, investing in the latest identification and communication technology for supply chain management will not have the desired impact. This makes it all the more important that companies start optimizing their basic processes now, shaping them with an eye to the latest identification technology and what it will mean for them. Supply chain event management is not a matter that can be put off until a later date. Companies need to start acting today, automating their processes step by step. As they progress, they will find that most of the efficiency gains are actually indirect – coming from the improvements in their basic processes. In this sense, supply chain event management is more than just a vision for the future. It offers real potential that companies can begin tapping into today.

Design, Implementation and Evaluation of a Performance Measurement System for Virtual Enterprises in the Aerospace Industry

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Introduction

Requirements towards suppliers in the aerospace industry are currently changing significantly. Aircraft manufacturers expect their suppliers not only to deliver components and modules but also to develop, manufacture and integrate complex systems independently. Furthermore, suppliers are expected to provide logistic support over the complete life cycle of their system, especially during their operation, e.g. with airlines. Thus, first-tier-suppliers must on the one hand offer the required competencies for the complex process of system integration, and on the other hand possess a sufficient financial capacity to carry the risks of product development. These requirements are met only by few companies, leading to a drastic reduction of potential first-tier suppliers. Companies that do not meet the mentioned requirements have to re-position within the supply-chain and become suppliers of subsystems or sub-subsystems for manufacturers of systems.

For the small and medium enterprises (SME) affected the required competencies and capacities concerning development, engineering and integration as well as the management of the complete supply-chain can often only be provided through flexible cooperation between firms. A promising form of cooperation in this context is the Virtual Enterprise (VE). A Virtual Enterprise is a temporary inter-organisational cooperation between several legally independent companies in an IT-supported network that can be flexibly configured on short notice to process a certain order. The basis for setting up these flexible networks for order processing is provided by a stable, long-term network of firms which ideally relies on established relationships.

But particularly SME face challenges concerning the configuration and development of inter-organisational cooperation, especially in the field of product development.

Companies in other European countries are, compared to their German competitors, better prepared for the structural changes in the supply-chain because the suppliers in these countries are less fragmented (BDLI 2005). The resulting tough competition is further increased by cost pressure through growing commodity prices and the currency risk, since commercial transactions in the aerospace industry are usually conducted in US dollars.

Faced with these conditions, SME often depend on the immediate financial success of inter-organisational cooperation. A critical success factor for cooperation is effective and efficient cooperation management in order to minimise transaction costs. Within single companies, management instruments such as performance measurement systems (PMS) are used in order to bring the organisation's activities in line with its objectives. However, up to now there are hardly any methods and instruments which support a targeted direction of inter-organisational processes while taking cooperation-specific success factors and objectives into account. For flexible cooperation along the supply-chain in form of virtual organisation especially, there are neither scientific results nor hands-on reports.

This article presents a framework for a performance measurement system for flexible cooperation in the aerospace industry. The implementation, application and evaluation of the performance measurement system is shown in a case study of a cooperative product development project carried out in a consortium of six SME in the aerospace industry. Finally, the necessity of adequate IT-support for performance measurement in inter-organisational cooperation is discussed and the potential benefits of supply-chain event management concepts in this context are pointed out.

A Performance Measurement System for VE

Until now, no performance measurement system for cooperation in Virtual Enterprises has been developed. However, there have been several research activities dealing with other types of inter-organisational cooperation (e.g. SCOR-Model (Supply-Chain Council 2005), SCEM-Concept (Ijioui et al. 2006), Network Balanced Scorecard (Jehle a. Schulze 2005). Using these approaches as a basis, a methodology for developing a PMS for VE including a framework for the PMS as well as a process model for implementation including supporting instruments was developed. The PMS developed using this methodology are supposed to fulfil the following functions:

- Information function (representation of relevant information adequate for the needs of the user)
- Regulation function (setting of target values for decision problems)
- Explanation function (extension of the information function: representation of interdependencies and explanation of reasons for changes in certain values)

- Coordination function (extension of the regulation function: coordination of goals of single organisational units according to an overall organisational target)

Furthermore, to fulfil these functions the performance measures used must accurately measure what they are to measure (validity). Finally the application of the PMS should provide an adequate cost-benefit ratio (utility).

Framework

The following framework was developed as a basis for a performance measurement system suitable for VE that overcomes the limitations of existing approaches for inter-organisational cooperation (Fig. 1).

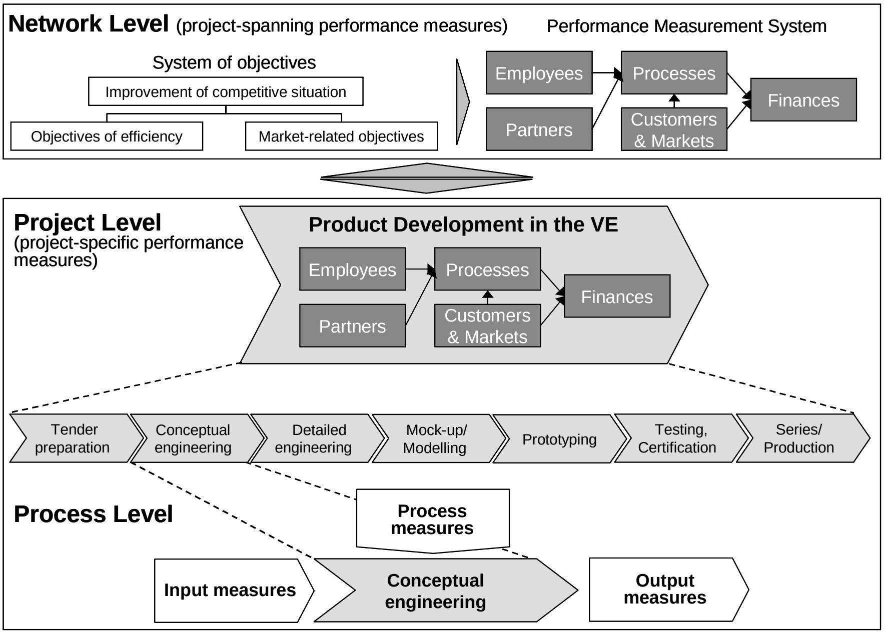

Fig. 1. Framework for a performance measurement system for VE

The basic structure of the performance measurement system differentiates, according to the structure of a VE, between a network level, a project level and a process level. On network level the performance measurement system consists of project-spanning performance measures, which represent the strategy of the complete network and measure the achievement of network objectives over all cooperation projects. Project level contains performance measures for managing con-

crete projects that are processed by consortiums within the network. These consortiums are configured depending on the requirements of an order at hand.
Project level, in turn, is hierarchically structured into overall performance measures for a complete cooperation project and performance measures for specific processes of a project (process level) that are processed by different partners. The performance measures of the process level are assigned to the processes of a simple reference development process beginning with the tender preparation and ending with the production process.

In addition to this hierarchical structure, the framework systemises performance measures according to the content of the measures. On network level the performance measures are structured according to the supply-chain Balanced Scorecard (BSC) using the five perspectives finances, business processes, markets/ customers, employees and partners (Jehle a. Schulze im Hove 2005).

- The financial perspective represents the financial targets of the Virtual Enterprise. This perspective occupies a central position since objectives and measures of the other perspectives should be oriented towards this perspective. Possible measures within this perspective are the net profit ratio or the total turnover in cooperation projects.

- The process perspective represents requirements towards the business processes of the VE. Relevant measures are, e.g., the throughput time, the service level or the proportion of innovative products in product development projects.

- The customer perspective represents the achievement of customer satisfaction and contains measures such as the customer satisfaction level or the proportion of projects with a certain customer.

- The employee perspective complies with the learning and innovation perspective of the classical BSC. Since employees are the crucial factor in knowledge intensive cooperation, this perspective contains measures such as employee fluctuation or the degree of conformation with target competence profiles.

- The partner perspective represents the relations between the partner firms of the VE. It contains measures such as the level of cooperation quality or the degree of cooperation stability.

The performance measures of the network level are concretised on project level. Accordingly, the project performance measures are structured in the five perspectives as mentioned above. A process orientation of the performance measures is not necessary on these levels, since a summary of the results of one or several projects is usually required for management.

On process level more detailed performance measures are necessary to enable the process owners to effectively manage their processes (Stausberg 2003). Therefore, on process level, the categorisation in perspectives is replaced by a process oriented categorisation of performance measures in input, process and output measures. Input measures enable an evaluation of influences that belong to the field of responsibility of suppliers, process measures enable the assessment of influences that belong to the field of responsibility of the process owner and output measures enable the evaluation of process effectiveness and efficiency.

These performance measures on process level are collected and analysed by the specific network partner responsible for the particular process while performance measures on project level are acquired across companies.

With this basic framework a balanced performance measurement system can be achieved through the use of BSC-perspectives. Since the measures of the upper levels serve as orientation for deriving measures on process level, a balanced system can be achieved on all levels.

The description of the product development process and the categorisation of the related performance measures within the framework leads to relations between the performance measures which form the single measures to a performance measurement system. Horizontal relations between measures, i.e. between subprocesses or between partners, are ensured through the process oriented categorisation of input, process and output measures. Output measures of the testing process, for example, are input measures for the production process.

Vertical relations between measures are formed by a participative process of concretising measures of the upper levels on the lower levels and in turn aggregating measures of the lower levels into measures of the upper levels. Throughput times, for example, can be aggregated by adding throughput times of the partners. However, to draw up an index for assessing the quality of cooperation based on the questioning of partners, further rules for aggregation are necessary. In this case, the average value of the partners' indexes as well as the standard deviation would be sensible measures.

The network and the project level contain mainly output measures in a sense of a management summary. In this respect the employee perspective is an exception since employee-related measures are process measures. Because of the importance of employee performance in knowledge intensive cooperation, these measures are also displayed on the top levels. Output measures of the sub-processes on process level are process measures on project level.

Implementation of the Performance Measurement System

The design of a PMS for a specific organisation and the subsequent implementation of the PMS requires a systematic approach (Neely et al. 2000). For the implementation of the performance measurement system, as specified above, the following steps are suggested:

1. Analysis of existing performance measurement systems in the cooperation, i.e. in the partner companies of the cooperation

2. Participative design of the performance measurement system according to the described framework
3. Specification of an organisational concept for the performance measurement system
4. Selection of an adequate IT-support for the performance measurement system
5. Implementation of the system

For each step of the implementation process supporting instruments were developed:

1. The analysis of the current state of performance measurement systems is based on checking the compliance with design principles of PMS. To carry out this analysis a questionnaire was developed, which enables the quick and systematic identification of possibilities for improvement in the partners‘ performance measurement systems (Peters et al. 2006).

2. The participative design of the performance measurement system is structured according to the presented framework. In a preparatory workshop with representatives of the network partners the objectives and success factors of the VE are identified. Performance measures covering the five perspectives of the framework are then deduced. Following this principle, the performance measures are detailed for particular projects on project level. The workshops are structured using the following central questions:

   - What are the objectives of the cooperation within the VE?
   - Which factors within the VE allow the cooperation partners to outperform competitors?
   - What are the most important prerequisites for reaching the network objectives?
   - Which performance measures are suitable for measuring the achievement of the network objectives?
   - Which performance measures are suitable for monitoring the compliance with the network success factors?

   In additional workshops with representatives of particular partners of the project consortium the overall project performance measures are further detailed for each process step. If necessary, the reference process can be modified according to project characteristics at hand.

   While the workshops on network and overall project level use cooperation objectives and success factors to deduct performance measures, on the process level the requirements towards preliminary processes are used to identify relevant process performance measures. The following central questions are used to structure the workshops on the process level:

- What are the essential requirements towards the results of the considered process step?
- Which output measures are suitable for representing these requirements?
- Which performance measures are necessary for managing the considered process in order to achieve the desired output?
- What are the essential requirements towards the results of preliminary processes?
- Which input measures are suitable for representing these requirements?

To conclude the design of the performance measurement system, the performance measures on process level are experimentally aggregated onto project and network level to check the consistency throughout the hierarchical levels. If necessary, adjustments are made.

The supporting instruments of this process step are the structure for the PMS, workshop guidelines and catalogues of possible performance measures for the platform, the project and the process level. On platform level the measures are structured according to the goals and success factors that hey are supposed to represent. On process level the performance measures are structured according to the sub-processes of the product development process.

3. The specification of an organisational concept is of special importance since administration of a performance measurement system becomes more complex in an inter-organisational context. The assignment of responsibilities for collection, analysis and visualisation of data as well as authorisations for administration and use of different levels and components of the performance measurement system must be carefully considered. Therefore, these aspects should be defined in a specification sheet for each performance measure in the system (Fig. 2).

4. Considering the cost-benefit-ratio for collection, processing and analysis of data and the implementation of an authorisation system, the performance measurement system should be IT-based. Therefore, adequate IT-support should be selected (an overview of existing software-tools can be found e.g. under www.controllingportal.de).

5. The final step is the actual implementation of the IT-based performance measurement system in a pilot project within the VE. To evaluate the effectiveness of the new PMS the questionnaire for the analysis of PMS can be applied a second time in the sense of a before-after-comparison.

Specification Sheet „Performance Measures“
Objective: Why is this performance measure analysed?
Scope: For which area of the Virtual Enterprise is this performance measure valid?
Definition: Which factors does the performance measure contain and how can they be defined?
Calculation formula: Which is the formula to calculate values of the performance measure?
Data sources: Which basic data for the performance measure already exists? How can these basic data be acquired?
Dates and cycles for collection/ analysis: At which specific dates is the data collected/ analysed?
Target-Values and alert thresholds: Are target values and alert thresholds specified for the performance measure? At which dates are target values specified?
Data visualization: How are the data visualised (tables, diagrams etc.)?
Person in charge: Who is responsible for the collection, analysis and visualisation of the data?
Distribution list: Who are the addressees of the performance measure?

Fig. 2. Specification sheet for performance measures

In following projects continuous improvement of the performance measurement system should take place.

Fig. 3 summarises the steps of the implementation process and the supporting instruments.

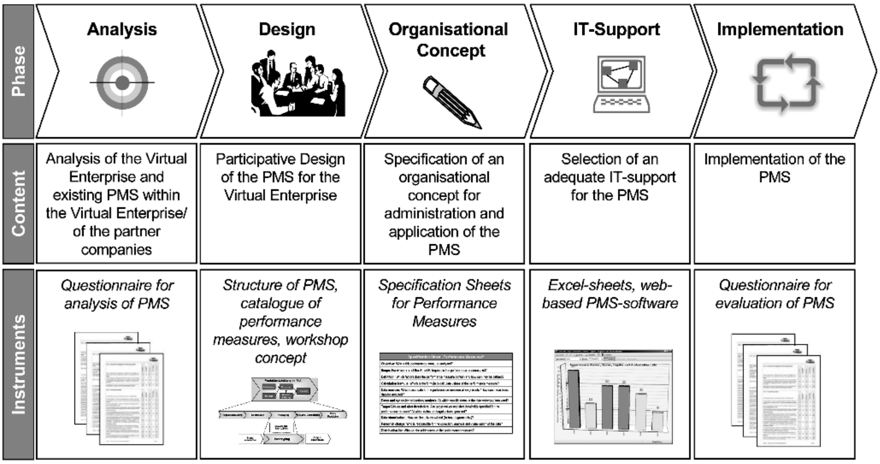

Fig. 3. Implementation process of the PMS

Case Study

Implementation of the PMS

The developed framework, including the supporting instruments, was applied and evaluated in a case study which was carried out within a research project. The case study dealt with the processing of an engineering project within a Virtual Enterprise. As engineering task, the development of a playground and entertainment area for a wide body aircraft was chosen and carried out within a consortium of six SME of the aerospace industry. A seventh company acted as a network-broker and assisted in the network configuration but had no active part in the actual project processing.

Fig. 4 shows the steps of the engineering project in a simplified process model. The level of abstraction as displayed in this model was chosen for the implementation of the process performance measures.

Fig. 4. Process steps of the engineering project

According to the steps of implementation as described above, an analysis of the existing performance measurement systems within the consortium was first carried out. The results of the analysis showed that the existing performance measurement systems left room for improvement concerning general design principles as well as cooperation-specific design principles. Due to these findings, the implementation of the VE-specific performance measurement system appeared reasonable. Next, a workshop for identifying the network objectives was carried out with representatives of the network partners. After prioritising the first collection of objectives, the following main objectives of cooperation were identified:

- Cost saving in marketing, project acquisition and tender preparation
- Constant capacity utilisation
- Expansion of service and product offering
- Access to markets
- Optimisation of customer's benefit
- Sales/ profit increase
- Decrease of throughput times
- Increase in bargaining power with customers and suppliers

Furthermore, several success factors for the achievement of these objectives in the Virtual Enterprise were drawn up:

- Flexibility concerning time, capacity and range of service offering
- Competitiveness of service and product offering
- Quality of cooperation (communication, values of cooperation, performance behaviour of partners, climate of cooperation)
- Personal contacts between partners/ experience from prior cooperation
- Publicity of the Virtual Enterprise/ of the partners

In a second phase of the workshop on network level, the essential performance measures that represent these network objectives and success factors were identified. Next, this procedure was repeated for project level. Since performance measures on project level represent a concretisation of network performance measures for particular projects, there are only slight differences between the selected

performance of these two levels. Fig. 5 shows the performance measures for network level and project level.

Performance Measures on Network Level

Finances	Processes	Customers & Markets	Employees	Partners
• Costs of network administration • Project acquisition costs • Adherence to project costs • Profit • Sales	• Adherence to delivery dates • Service level • Reclamation quota	• Customer satisfaction index • Proportion of sales with one customer • Level of publicity	• Compliance with target competence profiles • Employee satisfaction index	• Degree of compliance with target profiles • Network evaluation index

Performance Measures on Project Level

Finances	Processes	Customers & Markets	Employees	Partners
• Adherence to project costs • Project profit • Project sales	• Adherence to delivery dates • Reclamation quota	• Customer satisfaction index	• Compliance with target competence profiles • Employee satisfaction index • Personnel continuity	• Degree of compliance with target profiles • Network evaluation index

Fig. 5. Performance measures on the network and project levels

With the overall performance measures for possible projects established, the process-oriented performance measures for each sub-process as specified in Fig. 4 were identified in four further workshops. This means, one workshop was carried out for each process step except work scheduling and production, which were dealt with in one combined workshop. These workshops were carried out with managers and project managers of the project consortium which were involved in the considered process step. This lead to numbers of two to six partner representatives that were involved in the workshops. Fig. 6 shows the input, process and output measures for the design process as an example for the workshop results.

Horizontal links between the performance measures of the different processes were thus achieved by using corresponding input and output measures throughout the complete process chain. In this case, the performance measures "adherence to delivery dates" and a "reclamation quota" (in the case of the design process "Proportion of documentation requires amendment") represent the central requirements at the process interfaces.

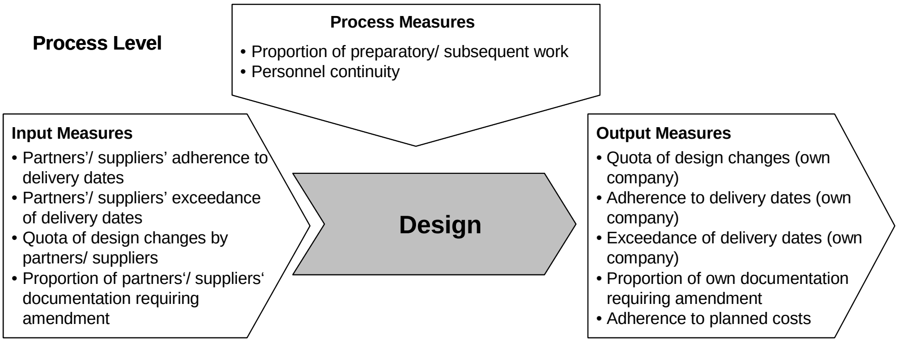

Fig. 6. Performance measures for construction process

Fig. 7 shows a detailed example of the performance measures that are used by partner 3 to monitor the input of the other partners 1 and 2 that are involved in the design process. The performance measures of the partners 1 and 2 are integrated on the right hand side of the figure, while the left hand side shows the individual measures of each partner. The integrated values are calculated by using the basic data of the partners' measures and therefore do not necessarily comply with the mean values of the measures given in the figure.

Process Level

a) Adherence to delivery dates				b) Quota of design changes			
no. kept deadlines / no. deadlines				no. design changes / no. components			
Partner 1		**Partner 2**		**Partner 1**		**Partner 2**	
target	actual	target	actual	target	actual	target	actual
1	1	1	0,5	1	0,1	1	0
c) Exceedance of delivery dates				d) Proportion of amended documents			
Σ exceeded dates / project duration				no. amended documents / no. docum.			
Partner 1		**Partner 2**		**Partner 1**		**Partner 2**	
target	actual	target	actual	target	actual	target	actual
0,05	0	0,05	0,02	0,1	0,33	0,1	0

Aggregated input measures for partner 3

Design (Partner 3)

	tar.	act.
a)	1	0,75
b)	1	0,08
c)	0,05	0,02
d)	0,1	0,2

Fig. 7. Input measures of the design process for partner 3

Vertical links between the different levels of the performance measurement system result from the aggregation of central process performance measures.

In this case, the performance measures “adherence to costs”, “adherence to delivery dates”, “reclamation quota” and “personnel continuity” are acquired over all processes and partners and aggregated on project level. This aggregation allows the project manager a quick overview of the essential measures of the project. If required, he/ she can use the more detailed data of process level as a basis for interpretation. Fig. 8 shows the aggregation of the performance measure “adherence to project costs” from process onto project level using data from the project phases “design” to “work scheduling”.

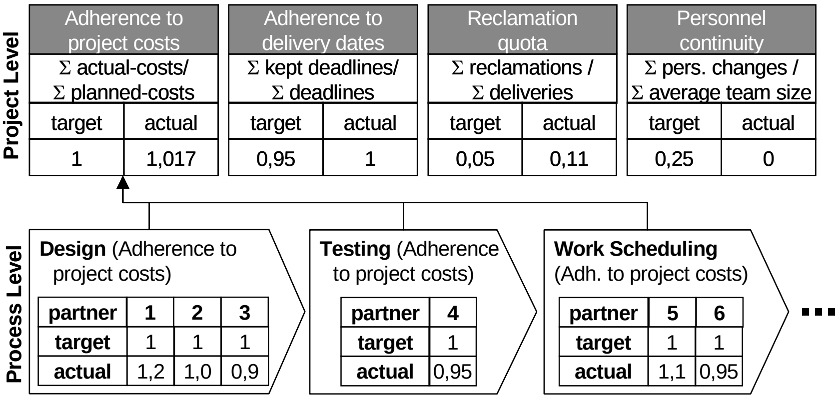

Fig. 8. Aggregation of performance measures on the process level onto project level (Example: adherence to project costs)

Further performance measures, though, are determined over all processes on project level. The same applies for the vertical links between project and network level.

After having established the performance measurement system on all levels, each performance measure was defined in detail using the specification sheets as mentioned above. Moreover, Microsoft Excel sheets for the collection, analysis and visualisation of the data were drawn up.

Up to this step, the process of developing and implementing the performance measurement system was supported and moderated by the scientific support of the project. The additional phases of implementation, data collection and use of the performance measurement system were then continued by the industrial partners.

The development of the performance measurement system did not show such a linear progression as described so far. It was instead characterised by several loops between the different levels until a sufficient integration of the different levels and processes was reached and the performance measurement system was approved by all partners.

Evaluation of the PMS

According to the implementation process of the PMS (Fig. 3) an evaluation of the new PMS should be carried out after the completed implementation. In the case study the questionnaire for the analysis of PMS was applied a second time and the results were compared to the analysis of the initial situation (step 1 of the implementation procedure). Thus, an assessment of the improvements concerning critical functions of the PMS compared to the initial situation is possible. In addition, possibilities for continuous improvement of the PMS can be identified.

To carry out the evaluation, selected questions of the mentioned questionnaire (sections of the questionnaire concerning the effectiveness and the cost-benefit ratio of the PMS) were asked again, after the engineering project had been completed. The questions were modified slightly, so that it was apparent that the items refer to the new PMS. The following aspects were covered with nine items:

1. Change of the validity of the PMS
2. Change of the information function of the PMS
3. Change of the explanation function of the PMS
4. Change of the regulation function of the PMS
5. Change of the coordination function of the PMS
6. Change of the cost-benefit-ratio

To enable a quick and simple data collection the questions could be answered by marking answers with a cross on a pre-defined scale (5-level Likert-scale). The survey was carried out among 12 project managers and project engineers that had already taken part in the survey concerning the initial situation. Accordingly two to three employees of each network partner involved were questioned. For the analysis the answers of the two surveys were compared as shown in Fig. 9.

Fig. 9 shows that, according to the assessment of the project managers and project engineers involved in the engineering project, the overall effectiveness of performance measurement could be improved by the implementation of the new PMS. The explanation function (3) and the coordination function (5) had been rated comparatively low in the initial questioning. Significant improvement was achieved concerning these aspects.

The validity (1) and the cost-benefit ratio had received rather high ratings in the first questioning. However, the evaluation also shows improvement of these aspects. Concerning the information function (2) and the regulation function (4) of the PMS the changes are not as significant. The information function was rated very high with a medium value of 4.25 in the initial survey. While the medium value in the second survey reaches only 4.08, still seven of the 12 persons involved rated the information function better or the same as in the initial situation. Accordingly the fulfilment of the information function can still be regarded as satisfactory.

The regulation function (4) also received high ratings in the initial situation. In the second survey similarly high values were reached. Altogether the results of the evaluation show that the additional functions of explanation and coordination, which separate systems of performance measures from single measures, could be improved significantly. These results confirm that SME, although they work with performance measures, usually do not integrate them into a coherent system which can fulfil the explanation and coordination functions adequately.

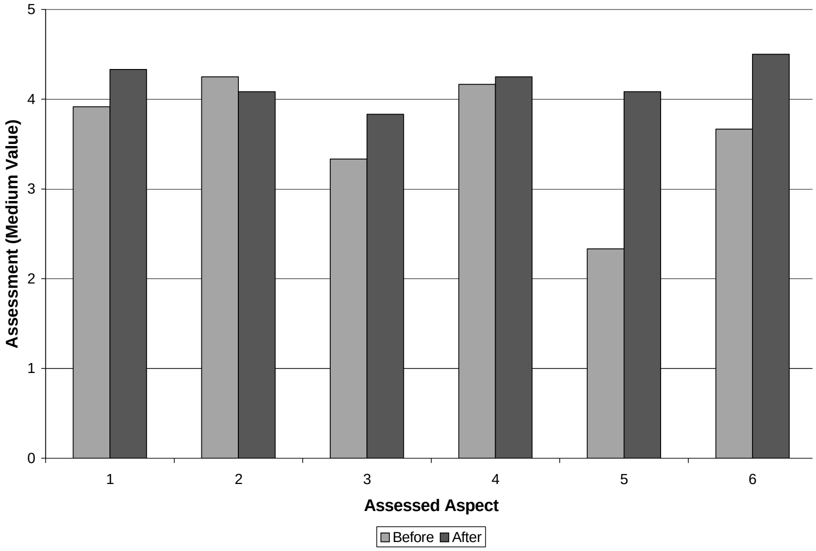

Fig. 9. Results of the before-after comparison

The systematic approach for developing a hierarchically structured PMS while considering the interfaces of cross-company processes, allowed the improvement of these functions.

Summary and Outlook

The article presented a framework for a performance measurement system for flexible cooperation, and illustrated the application of the framework in a case study describing the implementation of a performance measurement system for a cooperative product development project carried out in a consortium of six SME in the aerospace industry.

The presented framework consists of a performance measurement system on the network level, i.e. integrating all projects carried out within the network. These performance measures represent the overall objectives of the cooperation in the VE. The performance measures of the network are concretised for particular projects. The sub-processes of the projects in turn are processed by the VE-partners who integrate cooperation specific performance measures into their company performance measurement systems. These measures are elements of the overall performance measurement system of the cooperation project. Thus, the framework ensures the orientation of the partners' performance measurement systems towards the overall network objectives.

The extent of the integration of cooperation specific performance measures in company performance measurement systems can be varied according to individual needs. A partner company that is only sporadically involved in cooperation activities should concentrate on a few relevant cooperation specific measures. Partners who predominantly operate in cooperation with others may prefer to design their complete performance measurement system for cooperative work.

Due to the perspectives of the Supply-Chain-BSC used on network and project level, the framework allows for a balanced performance measurement system. Nevertheless, a more detailed, process-oriented approach is integrated in the framework on process level of particular projects. Furthermore, the framework allows for the organisational structure of Virtual Enterprises by differentiating between different levels.

On process level, the input-/ output-structure of the performance measurement system supports the representation of the interfaces between partner companies over the complete process chain. Thus, the performance measurement system can fulfil its coordinating function within inter-organisational cooperation.

The framework also allows the consideration of different objectives on process and overall project level while coordinating all activities in accordance with the overall network objectives. Cooperation-specific objectives are explicitly integrated into the system as a result of the suggested procedure for implementing the performance measurement system. In addition, the suggested participative approach supports the harmonisation of performance level between sub-processes and between levels, thus allowing an integrated performance measurement system for the complete Virtual Enterprise.

The presented framework also allows certain flexibility, since sub-processes and process-specific performance measures can be additionally integrated or exchanged according to the requirements of specific projects.

The evaluation of the developed PMS carried out as a before-after comparison in the presented case study showed an overall improvement of the performance measurement in the companies involved compared to the initial situation. Especially the cost-benefit ratio and the functions of explanation and coordination, which separate Systems of performance measures from single measures, could be improved significantly. The benefit of the structure for the PMS and the systematic implementation process, which ensures the representation of interdependencies by the PMS, could thus be confirmed. Concerning the validity of the PMS as well as the information and regulation functions, which had already been rated positively in the initial situation, similarly positive results or even slight improvements could be achieved.

Finally, a central realisation of the case study was that the IT-support of performance measurement systems in inter-organisational cooperation requires special consideration. Many SME implement their performance measurement system based on Microsoft Excel which basically provides most of the required functions (Samtleben et al. 2005). In the distributed environment of a Virtual Enterprise, further aspects become relevant. Data must be collected from several, distributed sources and then be integrated into standardised measures. The IT-support must also enable a concept of authorisation for administration and utilisation of the performance measurement system in a distributed context.

Regarding these requirements, the concept of supply-chain event management offers a promising solution for an integrated IT-support of performance measurement systems. SCEM systems explicitly integrate the component “measure” in order to evaluate supply chain performance as a basis of for initiating certain actions. Beyond this, SCEM systems automatically provide many of the data required for performance measures and also offer possibilities of automated analysis of the data as well as functions of alerting process owners in case of variation from target values. Thus, performance measures such as throughput times or adherence to delivery dates, that so far had to be acquired manually, can be supplied directly through the SCEM system.

Keeping the essential cost-benefit-ratio of performance measurement systems in mind, the integration of performance measurement systems in SCEM systems seems an applicable solution. However, due to the predominant application of SCEM in logistics networks up to now, certain adaptations for further fields of application are required. In order to implement an SCEM system for product development projects, as shown in the case study, different objects, workflows and standards must be established to enable the representation of less structured development processes.

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Conceptual Design and Case Studies

of

Supply **C**hain **E**vent **M**anagement

Usage and Promotion of Employee Potentials in Modern Production Systems

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Introduction

Production strategies change the working environment. In the 1980s CIM introduced the application of computers in production (Wildemann 1990). Later Lean Production (Womack et al. 1990) gave reason for numerous restructuring projects in the automobile industry. Iacocca's Agile Production (Iacocca Institute 1990) continued this. Since the late 1990s, holistic production systems are the tool to adapt Toyotas production system to western mass production. Since around the turn of this century, concepts of Supply Chain Management as an element of the holistic systems have directed the entire enterprise towards the needs of the customer and aim for a considerable acceleration of all processes. The ability to react towards sudden and unplanned events in the framework of the Supply Chain Event Management (SCEM) demands additional adaptive regulation and controlling concepts in all areas of the business.

All recognised strategies share the fact that company employees are confronted with new systems, methods and processes. Though still engaged in the production of goods, production employees are required to deal with an ever-increasing amount of tasks previously dealt with by administrative personnel. Alongside technical innovations like new machines with a higher degree of automation and equipped with an overall and permanent network connection to the operational ICT system for production planning and programming, along with controlling and administration, it is particularly innovations in organisational working concepts, especially in group and team work, that alter the personnel requirements. These innovations create the constant need for further training, often in areas that do not fall into the core competencies of a particular profession. The production employees must deepen their knowledge and integrate it with experience to be up to the daily demands in the production area, to be able to react flexibly and purposefully to the particular demands of the customer, or to be able to react to quality problems and, within the framework of independent optimisation cycles (Kaizen) (Imai 1986) to alter the configuration of their workstations accordingly.

For the production management therefore, a paradigm change arises. Employees are less a cause of expense and weakness in the system that have to be reduced or eliminated through effective streamlining and automation, but are rather to be seen as essential elements for the control and harmonic regulation in a modern, flexible and failure-reduced production system.

First, it is necessary to do a systematic assessment of the employees' qualifications, along with the recognition and documentation of the requirements of the workstations. A comparison of these abilities and requirements indicates the qualification requirements, which must be addressed with an appropriate method. The design of measures aiming to address these qualification issues must consider social constraints; in this age gender specific parameters are just as important as the problem of extended working life. There are also the increasing problems of language barrier (due to migration background) or hidden illiteracy restricting further qualification of the employee. For this reason, training concepts have to be reconsidered and newly developed if the employees are to meet the constantly increasing requirements with the necessary safety and reliability. Concepts of learning and teaching must themselves be subject to ongoing evaluation and optimisation to meet the changing requirements.

With the increasing complexity of the production facilities and processes and the increasing quality requirements, it is becoming clear that the pure school-based training alone is insufficient to gain the necessary knowledge and abilities for the production area. Great importance is given to knowledge gained from experience (Böhle 2004). It is based on the subjective perception of the individual and, as this suggests, cannot be trained. Experience-based knowledge is necessary to recognize slowly developing problems and faults early in a running production process. With quality requirements becoming increasingly rigid the capabilities of the employees gain in importance. This experience-based knowledge is also paramount in securing the business processes, where knowledge and understanding of the adjacent process steps are of substantial importance.

The production management must recognize these problems and allow and encourage, through supervision of employment, the amassing of experience. Coaching and workstation partnerships ("Twins System") are proven methods to broaden the employee's experience. The outlay involved in this is hard to justify in present controlling systems since appropriate methods of measurement for the affectivity are non-existent or unproved at this moment in time. Research in existing production areas is impressive in showing that the knowledge of the employee, consisting of specialist content and the extensive collection of experience, is a clear advantage for the company in increasing further development in the direction of zero-defect-strategies and falling failure rates to the region of "<10ppm" (Welch 2001).

Lifelong learning and the collecting of experience are key-criteria in the functioning of modern production strategies.

Holistic Production Systems – Production Strategies Growing Together

The comparison of the European and the American automobile manufacturers with their Japanese competition, especially Toyota, a drastic deficit in all areas of the "traditional automobile producer" is shown (Womack et al. 1990). The Toyota Production System is seen to be the cause of success. In this, all areas of the business are involved in the application of suitable instruments and tools, and together aligned towards the company's objectives. The application of such a holistic production system is convincing in its clear improvement of cycle time, quality and the variant management. Furthermore, in reference to innovative cycles, technical innovation level and efficiency, the Japanese concept sets new milestones. Due to the well-known Far Eastern discipline and the outstanding employee motivation, start-up times are far less than in the western mass-production competitors.

Inspired by the successes of the Toyota Production System, many companies are trying to adapt the Japanese model. They are developing and implementing their own holistic production systems to suit their needs. Hereby, the systematic of these systems is essentially uniformly structured. The business strategies and their associated objectives are pooled and introduced over the whole company. The methods, concepts and activities of all areas must subordinate to these objectives and contribute to their achievement. In this manner, an orientation of the whole company is achieved.

All business areas are included in a holistic production system. Despite the name's reference to production, other business areas, even those that have only an indirect connection to production, e.g. human resources or sales, are also included. Furthermore, all tools, methods and instruments used are incorporated and assigned to the business areas (Fig. 1). The hereby-created concept features all known and relevant tools and methods and their responsibilities and arranges them in interdisciplinary business objectives.

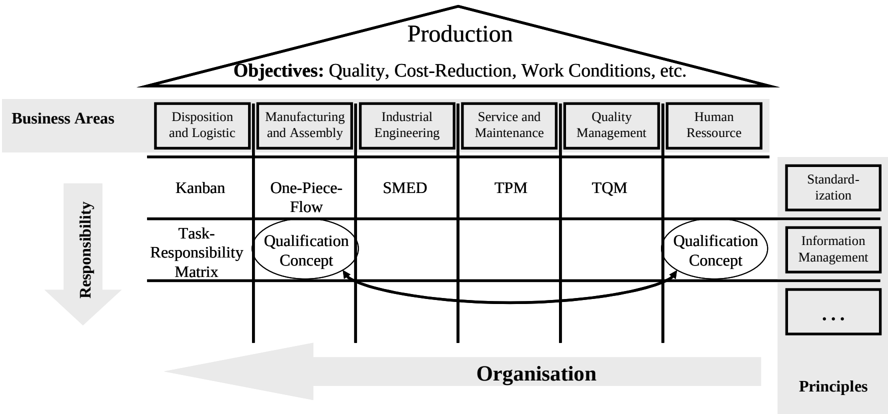

Fig. 1. Concept of a holistic production system

In order to reach the interdisciplinary business objectives, the rudimentary principles of the chosen course of action need to be examined and adapted. These principles guide further action and the implementation of methods. The control of material flow by means of Kanban can be classified under the principle of standardization as well as the principle of production improvement, so even utilization can be achieved. To guarantee a company-wide uniform tuning and application of all principles, methods and instruments, the coordination through a steering committee which clearly assigns liabilities and responsibilities and ensures that the methods align with the goal and results of the fulfilment of the business strategies, is needed.

Supply Chain Management (SCM) and Supply Chain Event Management (SCEM) are strategies that integrate orientation elements into holistic production-sytems. Hereby, customer benefits become the overall objectives that all business areas must support and fulfil. All measures and methods are oriented towards the overall objectives. This includes, for example, quality improvement, delivery reliability, and the real-time development and production of suitable customer-specific solutions. Also unplannable developments in demand and customer requirements are intercepted by SCM/SCEM strategies and dealt with in a flexible manner.

In order to function properly, holistic production systems must also incorporate the support of employee qualification as a method in the area of tools and instruments. Classically, under the responsibility of human resource management, a schooling and further training catalogue is scheduled. However, this very often sets a clear focus on administrative abilities and has the management as its target group. Training systems for the production employees that embrace changes in the spectrum of tasks at shop-floor level, and through schooling deal with the newly required knowledge, are normally underdeveloped, and when available, little used. Here it must be ensured that a training system for the production area and its employees is introduced and fostered. This training system can be placed under the direct responsibility of the manufacturing and assembly area, but should be supervised in cooperation with the human resources department. An allocation of this nature is sensible, above all against the background of the SCEM strategy-based rapid change reaction, due to the fact that their direct relation to the production can guarantee the topicality of the training measures.

Work Content – Qualification – Motivation

Altered and extended tasks and requirements of production employees also involve a rethinking of the understanding of productive activities. Depending on the characteristics of the production system, this consists only rarely of the direct actions such as manufacturing or assembling components, rather is represented by a catalogue of tasks which involves additional quality, supply, control and improvement tasks, along with responsibility.

Here it is irrelevant, although not without influence, whether individual or group responsibility occurs, these requirements are absolutely necessary for a functioning operation.

Clear and Explicit Definition of the Work Contents

All involved parties in the production must be informed of the expectations, responsibilities and activities that apply to them. This does not only apply to the individual workstation or the individual person themselves, but also in conjunction with other workstations and people. Especially in alterations in the material supply, as for example, with the introduction of a Kanban control system or a Milkrun, disagreements over responsibilities and tasks can arise. Moreover, long-standing structures in production can complicate planned redistributions of responsibilities and competencies aimed at increasing self-organisation at shop-floor level. To this end, an up-to-date, clear and explicit, generally accessible task-responsibility matrix supports an improvement in interface understanding through the elimination of uncertainties and ignorance regarding the responsibility structure of the production.

Work Content in the Qualification of Employees

Production employees should be qualified in a suitable manner to do all of their intended work content. So that the above discussed demands on modern products, and thereby on modern production systems, can be met, this qualification includes more than the relaying of work processes, organisation principles and product knowledge. The setting of objectives, understanding of methods, abilities for self-organisation and an understanding of ones own system and action limits determine action and operation generally, and the reaction to dealing with alterations and changes of plan. They are therefore important so that employees live up to their intended roles in system harmonisation and the expectations of the system configuration and process improvement.

Motivation

Motivation is the motor of every action (Stroebe a. Stroebe 1994) and has a direct effect on the work-willingness, deployment-willingness and the willingness to learn. Due to the facts that modern production systems live through their employees, change constantly and, as discussed earlier, are reliant on the active control, arrangement and reaction of their employees – motivation plays an all-important role. The causes of production promoting motivation are complex, and in their consequences often not obvious, for example, remuneration and security of employment. Hence, a targeted improvement of the motivation of employees is often very complicated and costly. On the other hand, one simple action of the management can easily lead to damage and deterioration in motivation (Sprenger 2002). For this reason decisions and information should always be examined under consideration of their effects on motivation. This also applies to work contents and qualification. An over-qualification without adaptation of the work contents can be just as demotivating as under-qualification and over-demand (Wunderer a. Kürbers 2003).

In the following, an emphasis will be given to the theme of qualification, and the manner in which the qualification of employees in a modern holistic production system can be approached will be shown. To this end, a qualification concept will be developed which embraces both the questions of qualification requirement and the suitable qualification methodology.

Qualification Requirement

The qualification requirement is shown by the deficit between the required level of qualification and the current level of qualification (qualification gap). This rather banal sounding recognition increases its significance with an understanding of the desired and current levels of qualification as constantly changing, dynamic and not of static dimension. The desired level of qualification takes on, as quickly as possible, all changes and novelties that affect the production. This includes product adaptations, organisational alterations, new customer guidelines, etc. On the other hand, the current level of qualification also changes, based on pre-qualification, learning, unlearning and forgetting. This dynamic effect is often not taken into calculation in the predefinition of the qualification requirements at shop-floor level. Hence there should be, as shown in figure 2 in a simplified version, an always up-to-date matrix in which the current and desired levels of qualification for given actions, workstations and tasks are clearly represented, and thereby critical qualification deficits are shown. Furthermore, this matrix should also consider the action, examination and qualification cycles of the employees, so that process competence, the topicality of the theoretical knowledge and the familiarity with the workstation are included.

Corporate-related Qualification Matrix	**Function**	**A**		**B**		**C**	
	Qualification	**Target**	**Actual**	**Target**	**Actual**	**Target**	**Actual**
Number of (available) Employee	**Process-sure**	**2**	**2**	**1**	**0**	**2**	**4**

Employee-related Qualification Matrix	**Function**		
	A	**B**	**C**
Eva Beispielfrau	**X**		**X**
Max Mustermann		**X**	
John Doe		**X**	**X**

Target Qualification:
includes all changes and novelties

Actual Qualification:
includes pre-Qualification, learning, unlearning and forgetting

Fig. 2. Documentation of the qualification requirement

It appears sensible to differentiate the work content requiring qualification for improved structuring and integration in the qualification concept. *Operation-related knowledge* (Fig. 3) describes the work content of the actual productive actions involved in the product manufacturing. On the other hand, *organisation-related knowledge* is the additionally allocated non-productive work content, such as objective setting, the participation in the controlling of the production system and the given responsibilities. For both of these areas, the qualification requirement is not oriented towards an informative knowledge level, but towards complete competence in the workstation with all its related work content.

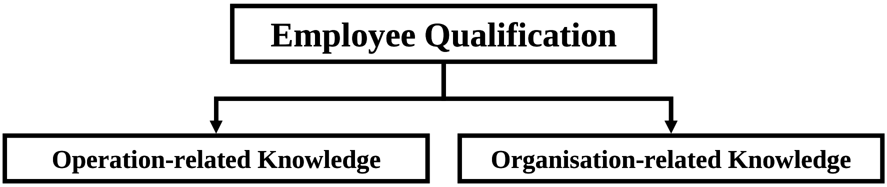

Fig. 3. Branches of employee qualification

Operation-related Knowledge

The classical principle of Taylorism recommends dividing productive actions into the smallest, simplest and most easily learnt working steps and then to distribute these in small parcels amongst the employees. Any controlling, supply and quality assurance tasks are carried out by hierarchically superior departments (first: Taylor 1911). This system has definitely the advantage that employees can be trained for a workstation in a very short time, and therefore are also easier to replace. The disadvantage is that, besides a frequently implied inhumanity, a fragmentation and distribution of work processes shows a higher personnel requirement and, in consequence, a reduced product and variant flexibility. In modern production systems, work content in the production for the individual production employee and for the individual workstation has become significantly more extensive, and involves the tasks to process different products and/or variants with the production resources at the workstation (see Fig. 4). Depending on the production methods, the integration of technology and the degree of automation, the work contents are differentiated by their characteristics. Consequently the requirements for employee qualification are also to be differently estimated.

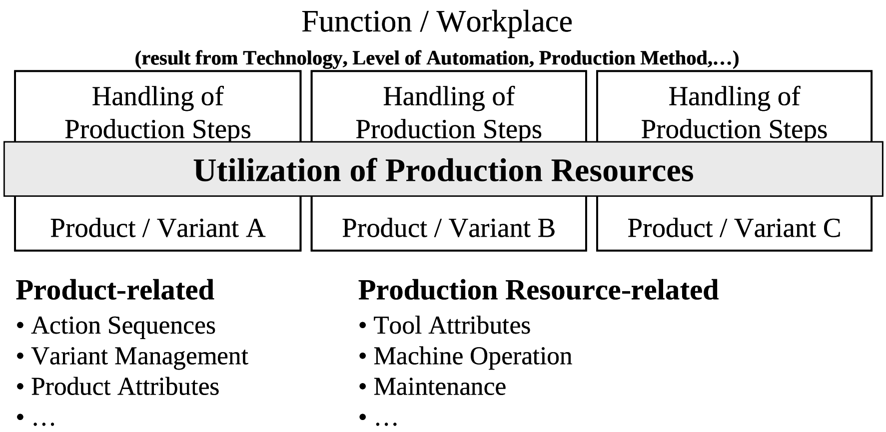

Fig. 4. Qualification requirements, production knowledge

In order to ensure the highest possible flexibility in the products to be processed, differing qualification focuses arise if the operational possibilities of the production resources are universally constructed, as by specialised, automated plants with a very limited product spectrum. This is made clearer by the comparison of a classical workshop manufacturing process with that of an automated production line.

In a workshop manufacturing process it is necessary that the employees know the possibilities, functions, properties and limits of their production resources. The operation is mainly controlled by this knowledge, which, in connection with the tasks and demands of the work piece, determines the actions and treatments. It is sensible and necessary to also match the associated employee qualifications to this field of tension. In contrast, at a workstation with product-specialised machines, knowledge of the type, properties, appearance and requirements of the product have more effect on the actions and treatment processes. Here, the possible leeway is more restricted. The qualification focuses would be sensibly placed with a reference to the product.

Organisation-related Knowledge

The focus of the qualification of production employees has been set in the past on a sure competency in the product processing, value-earning work contents. Due to the fact that modern production systems include flat hierarchies and increase the amount of organisational tasks at production level, the work contents of the production employee have changed.

A holistic production system includes a multitude of mutually agreed methods for all production-involved areas with the objective of improving the respective costs, quality, flexibility and delivery reliability. Because these methods mostly apply to and affect the lowest, operational level of the production, it must be ensured that the affected employees know and understand the entirety of the methods. As shown in figure 5, also in this case, analogously to the differentiation of the value-earning actions at the workstation in product and production resources, a differentiation is made between the special methods applied at the workstation and the knowledge of the method mix, its orientation, the objective(s) and the individual's position and significance in the production structure.

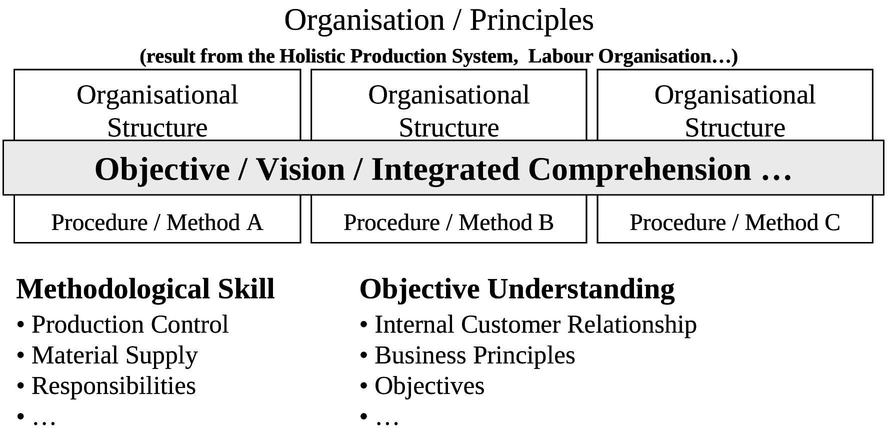

Fig. 5. Qualification requirement, organisation knowledge

The bandwidth of work contents that can be handed over to the production level, originating from hierarchically superior separate departments is very broad and can include controlling tasks, quality control, material supply tasks, along with the communication and self-organisation in workgroups. In order for a reorganisation to function, the employees have to know the new, additional tasks, their connected methods and work content, the strategies and, with connection to motivation, the reciprocating alterations to work complexity and work load. A model of the introduction of a Kanban controlling system will serve as an example.

The employees have to be informed that the responsibility for the material supply is being handed over to them. Without their active involvement, no material will be processed. Here, the work contents and processes for supply replenishment need to be determined and the necessary qualification achieved. On the introduction of a Kanban controlling system, it emerges additionally that the responsibility of the employees for the material supply ends straight after the ordering, and that an independent 'material hunt', or the accumulation of reserve stocks is counterproductive for the entire system and therefore is absolutely to be avoided. This also needs qualification.

Supplementary for the introduction of changes in responsibility and work content at the workstation, it should be stated that when possible it should not only involve the transfer of information about measures decided by the management. Rather the employees should be informed early about developments, and be involved in the development and decision process, certainly when it comes to its implementation.

Here again, the principle applies that the generation, the preservation and the improvement of motivation through the avoidance of demotivation should co-determine the company actions (Sprenger 2002).

A modern production system not only expects that the work content and tasks are carried out in a proper manner from its employees, but it also relies on employees to apply the different methods, techniques and areas at their interfaces in a harmonised manner for the increasing improvement of the system. For this to happen, it is necessary to have, on the one hand, a culture of self-initiative and an active will to play a formative role. On the other hand, a knowledge of the entire product framework with the relevant relationships is also an absolute prerequisite for the employee actions. This requirement is often not sufficiently considered in practice as it relates to qualification content that is manifestly difficult to connect to the work of a production employee, but which is necessary for a learning, stable, innovative and flexible production system. Obviously the employees also need concrete qualification content, such as the improvement of communication abilities or a clarification of the effects and significance of their own actions, alongside personal initiative and willingness to play a formative role. The training of methods of problem identification and development of solutions must therefore also include a scope of actions in order to create the motivation for the actual actions.

In summary the demands on modern products, and therefore also on modern production, require a rethinking away from classical production strategies of departments, hierarchies and division of labour, to more integrated, inter-disciplinary and holistic production strategies. Through the operation of this new rudimentary approach, the qualification and motivation demands on employees also change. Alongside the sure competence in product processing, value-earning actions, increased organisational tasks arise, for which a production employee initially has no pre-qualification. As this new task type also involves an increase in responsibility, it must be ensured that feelings of abuse or being over-challenged do not arise in the employees. At the same time, if the objective is also to change the attitudes of the employee so that they actively cooperate and co-organise the production strategies, then the incentives and motivation for this must be created. This involves, from the side of the management, an altered approach to delegation and controlling.

Qualification Mediation

A qualification concept connects the ascertainment of the qualification requirement with a suitable form of qualification mediation, which in return is dependent on the type and the content of the qualification requirement. In the following, the possibilities are structured into four different categories; work instructions, instruction, schooling and training.

Work Instructions

Work instructions are designed to support employees on site in their actions by the provision of relevant information in a suitable form, and to avoid uncertainties that arise from lack of knowledge. So that the allocation of provided information does not involve unnecessary time and effort, work instructions are usually physically attached to the relevant workstation, production resource and/or product. From experience, the quality of these work instructions as a qualification instrument is viewed with some scepticism. As in many areas, written work documents are exposed as going rapidly out of date and difficult to organise, so that very often work is carried out based on outdated documents. Moreover, reports from practice show that only with the aim of passing testing involved in an upcoming audit do companies check update and teach the contents of work instructions to employees, without the instructions being followed in real life. Obviously, work instructions are only of use when they are acknowledged, understood and adopted by the employees. Alongside the formulation in a language that the employees can read and understand, there are some rudimentary considerations to which work instructions should conform in order to improve the provision of information.

Longer texts and small fonts can have an off-putting effect on employees and inhibit the flow of information. Hence, a suitable degree of visualisation is a basic in improving acceptance. Analogously to technical drawings, one could conceivably use graphics, pictograms, illustrations and photographs on workstations, machines and plants. As an example in this connection, graphic intuitive package instructions can be named, which represent the correct procedure in step-by-step illustrations.

Depending on the workstation and plant, work instructions can be very extensive. The use of instructions can be made significantly easier when all work instructions follow a standard structure. This could, for example, occur in the form or the order of the themes to be handled. Such a standardisation also eases the maintenance and the creation of new instructions. In recent times, Intranet and web-based solutions have become an approved method in which the required information can be requested at the workstation via touch screen. Even multimedia applications with video and audio sequences are a sensible medium of support. Work instructions of this nature can be centrally maintained and are promptly available to all users after updating.

As described, a modern production system needs the active cooperation and co-organisation of all employees. In order to achieve this at all, one needs to have flexibility in configurations and the manner of carrying out activities. Work instructions are a medium, even when they are limited in their power of signalling, with which adjustments and alterations can be integrated and communicated through the employees in a problem-free manner.

Instruction

Qualification by instruction is widespread in many production systems. Equally in situations of new employment, new machines and plants, or temporary or holiday workers, the processes of demonstration and copying can mediate knowledge quickly and effectively. In this manner a rapid operational readiness can be achieved; training occurs on-the-job. One problem can be in the employees' process competence at the workstation, which might not necessarily be achieved in a short training phase concentrating on the action process. Experience shows that many companies have problems with quality and the interaction of production instruments in the summertime when the share of temporary and holiday workers is higher.

Although on-the-job training is widespread, only in a few cases is it carried out in a systematic, structured and suitable manner. Hence, in order to achieve an increase in process competence, the introduction of a training methodology can be helpful. As an example, the four-step method of work instructions can serve as a foundation; basically the process of work instruction hereby is divided into four steps (Schelten 1995):

1. Preparation: prerequisites achievement; attunement.
2. Demonstration: Give an overview ⇒ Go into details ⇒ move on quickly.
3. Understanding: Gain overview ⇒ Go into detail ⇒ rapid implementation.
4. Examination/Test: Practice alone; designate helper/contact person.

Another possibility to improve the instruction of process competence is in the representation and exercise of failures that could potentially arise. Complementary to the training of normal cases and the instruction of the correct course of action arising therefrom, it can be sensible to simulate probable error situations and the manner of tackling these at the workstation. In this manner, the recognition of error and malfunction situations and the correct reaction can be practiced. Such simulative instructions are especially suitable for organisational processes, as it is easier to simulate a malfunction in these than in technically complex machines and plants.

Schooling

Schooling is qualification through the structured mediation of information. The mediated information is thematic. Here it is sensible to examine the type and format of the schooling for its suitability, effect and sustainability. When possible, a pure lecture format should be avoided in favour of an autonomous learning format. Workshops that have the goal of an interactive processing of the subject matter, and documents that in their extent and form guarantee clarity can support the transfer of knowledge.

Training

Training means the mediation of knowledge and skills that are oriented towards the requirements of vocational activities. The qualification occurs in a long-term, structured schooling and teaching system. The manner in which this is carried out in private companies and in the public administration is, in Germany, planned and monitored by the relevant responsible Chamber. An alteration or suspension of the requirements is thus to be undertaken in consultation with the Chamber responsible for the training. Besides the adaptation of the training to the requirements of modern holistic production systems, this means the mediation of product, device and process knowledge and an appropriate qualification of organisational knowledge and social skills. To the organisational knowledge belong knowledge of the company structure, its material and information logistics and the applied methods in the production (Kanban, FIFO principle, JIT, contract control processes and production principles such as One-Piece-Flow and Levelling). The training of planning, communication, presentation and management skills is also sensible and helpful for the intended future application in an integrated modern production system, especially in the operation of group or team work in a flat hierarchical structure (Gerst et al. 2003).

In summary, the introduction and adaptation of a production system also means the adaptation of employee qualification. This is especially true for Supply Chain Management. Even before the introduction and the achievement of a process competent, frictionless operation, an understanding and knowledge of the strategies and their orientation must be generated. The qualification of all productive and non-productive actions is an absolute requirement so that a company can react flexibly to disruptive events. Analogously to the production activities, it is also necessary to develop a target-oriented concept for the qualification of organisational procedures, which allows and guarantees the mediation of the qualification requirement and also the mediation of knowledge and skills with a structured and methods-based methodology. In the same manner in which the qualification concept is tailored to the company-specific holistic production system with its relevant requirements, it should be ensured that this qualification concept, on the other hand, is understood as a part of the holistic system and is integrated into the methods and processes catalogue.

Experience – an Additional Qualification

Vocational work, similarly to all activities based on the qualification of contents, significance and effects, is only further developed and improved by actually doing the work. In this way the employee collects experience and applies this. Experience is coupled to an individual experience background and is stored in the memory as implicit knowledge, i.e. knowledge and abilities that are difficult to represent in an analytical form. A person is capable of acting in the correct manner without being able to explain this experienced-based action, or being conscious of the underlying decisions (Mertins a. Finkel 2004). This element of knowledge, known as *experience knowledge* is thus only recognisable in acute action situations and hence, only in its rudiments systematically qualifiable. As shown in figure 6, the qualified production and organisation knowledge is extended by experience knowledge.

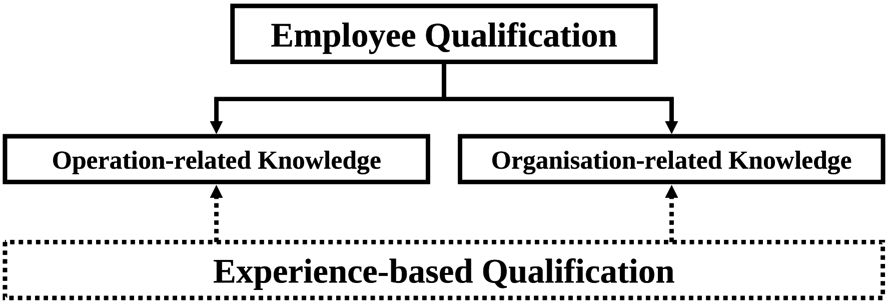

Fig. 6. Qualification enhancement through experience knowledge

For modern mutually agreed holistic production systems, experience knowledge is of great importance to all people carrying out the activities. The manner in which the people carry out the activities as a harmonizing entity in a complex system which guarantees the sequence and ability to react, along with a constant and continuous further development and improvement, relies on experience knowledge in a particular manner, since rational decisions are often too inert and exposed to too many influences in a multi-variant environment. For a company it should be important to encourage the acquisition, the application and the mediation of experience knowledge.

Acquisition of Experience Knowledge

Experience is linked to the individual background of experience acquisition. This shows clearly that the contents of the experience are determined by the experience background. If an employee cannot process appearing changes and developments during the work, or if the chance of recognising these does not exist, then experience knowledge cannot be acquired. Without the opportunity to act or react upon events, or recognize problems and develop solutions independently, the spectrum of achievable experience knowledge at the workstation is limited. The basic prerequisites to achieving experience knowledge are therefore room to manoeuvre and time; both areas which are difficult to establish in a production system under prevailing quality and cost pressure.

Application of Experience Knowledge

The idea of using the knowledge of employees for the company is not new. The rudiments of the bright ideas award scheme, the continual improvement process, or the widely applied Japanese Kaizen (Imai 1986), are based entirely on the activation and application of employee knowledge. In this, the application of experience knowledge, shown in figure 7, can occur in two completely different ways. For instance, arising problems can be tackled with technical and/or organizational measures; although these change the environment, so experience knowledge in this area becomes obsolete. This occurs, for example, with the application of Poka Yoke as a process for avoiding assembly errors. Without these structure-changing measures, the employees' experience knowledge improves the whole production. Both in the technical and the organizational view the process competence is improved. Sudden changes and faults can be intercepted and offset through the experience of the employee. In this manner the employees' experience knowledge is expanded recursively and is further attuned and improved through scopes of action.

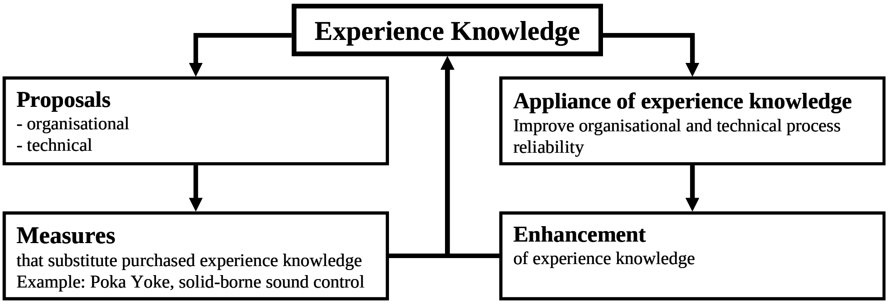

Fig. 7. Application of experience knowledge

In the practical implementation of the classical tools for the application of experience knowledge, one of the two rudiments stands mostly in the foreground. Since technical and organizational solutions have a simple cost structure in which the costs of the implementation can be represented against the saving potential of the measure, the focus of the most used methods for the application of employee knowledge is oriented towards the development of measures. For modern production systems both forms of experience knowledge application should be considered, since the complex production systems of our time are confronted with numerous products, methods and people, as well as increasing quality demands. They do not adapt unaided through the development and implementation of short-term measures, but are oriented towards sudden changes and spontaneous events for experienced employees operating within scopes of action.

Mediation of Experience Knowledge

If unlimited possibilities to mediate experience in the sense of sustainable instruction were to exist, some tasks would be significantly simplified. Child education is a well-known example in this context. Similar to this, the experience knowledge of the employee is not learned, but acquired through many years of activity and, very often through the experiencing of organizational and technical changes. Nevertheless there are subservient general conditions that allow the mediation of experience knowledge to a limited extent. The basic approaches involved are as old as manual skills themselves, and are obviously implemented in many companies. The mediation of qualification by teaching is carried out by experience employees. As experience knowledge can only be activated and sustainable learnt through the practice of activities and in connection with the work, the contents and procedures must be mediated in an action-oriented manner alongside the verbal communication. The trainers must, on their part be qualified for the carrying out of the qualification. Normally, the methods of active transmission of knowledge contents are positively assessed from both sides. The direct reference to subjects shows, in contrast to seminars in training facilities, a considerably larger effectivity and acceptance.

In summary, it is shown that the experience knowledge has great significance for the requirements of a modern production system. One should always consider however, that the experience knowledge of the employees can also affect necessary reforms and changes in the production process in a restricting and blocking manner. Equally valid is the fact that, whether experience knowledge should be acquired, applied or mediated, it requires scopes of activity, the possibilities of communication and time. However, scopes of activity that cede decisions to the production employees, along with an employee group that interchanges, coordinates, exchanges experience and mutually supports itself during the working hours do not fit superficially into the picture of optimised production. The clear assignment of productive and non-productive times that can be shown at any time by the controlling determine a development in which the individual freedoms, experience backgrounds, the exchange of working process and the cooperative arrangement of the workstation are difficult to implement.

Summary

The definition of the production worker is in a dilemma. As workforce the performance can be represented at all times by the ratio of working time to output. Because of relocation of tasks and responsibilities to the production level, the increasing non-productive times of the production worker must be considered. On the other hand, there are the sometimes exaggeratedly pursued thoughts to optimise production work, to reduce manpower and to guarantee an interchange ability of the employees. Hence qualification measures at shop floor level are often viewed with scepticism. On the one hand, in many places the opinion still exists that operative production work does not justify the claim to require such qualification. On the other hand training costs and the connected time spent away from the production of trainees can be shown exactly in costs. In comparison, the application of a systematic qualification concept cannot be, or can only with difficulty be, recorded, measured and represented. The effects on the key performance indicators in quality and production cannot be clearly categorised; obviated faults and solved problems on the production level are not recorded. This substantially aggravates the communication of the significance of a quality concept against other cost controlling provisions.

Even though difficult to record in numbers and values, the significance of the qualified employees cannot be rated highly enough. A complex production system can only work in a stable manner if controlled by them. If the target guidelines for such a system also increase to warranty flexibility, short reaction times and customer requirement orientation, an active thinking, and thereby trained employee, is required that co-arranges and improves the production.

Through the relocation of administrative tasks formerly carried out at a superior hierarchical level to the production area, many methods and tools are used that are not included in the usual job definitions. Systematic training concepts, which are oriented towards the dynamic of the required content, and are controlled through monitoring the employee’s required qualifications, can close the qualification gap. The goal is a production worker, optimally trained for the workstation, who has a clear understanding of all other business procedures and can think trans-sectorally for the company. Besides analytical knowledge content, experienced based knowledge elements are required in many cases. This can only be acquired if the employee is guaranteed the freedom to act and given the possibility of interdisciplinary communication. Irrespective of how the rudiments of a modern productions system are chosen, to be successful it needs to be comprehended and adopted by the employee.

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Added Value by Outsourcing of SCEM Solutions: Background and Technical Basis

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Introduction

Enterprises successfully practising supply chain management generally have a higher profit margin. Currently it is, however, very difficult for many enterprises to recover the spent capital expenditure. Until now the traditional target of outsourcing was cost saving. Meanwhile quality assurance and preserving enterprise-external expert know-how are pushing to the fore. This becomes more and more a prerequisite to compete at the world market in general. Thus, outsourcing is and remains an important business model. In the traditional comparison German enterprises, for example, were more reserved regarding outsourcing. Whereas preferably projects easily to be delimited were given to external service providers in the past, it nowadays are increasingly complex fields entirely integrated in the enterprise not seldom requiring more than only one expert. In the course of internationalization and export orientation also logistics is continuously developing. It has become a main component of the world market. In contrast to the fields of transport and warehouse for added value services as network management or in the procurement, order and start-up management a considerably higher growth potential is to be expected. Here, instead of simple fulfilment of tasks and pure cost focusing, an increasing innovation generation and sustainable gain for the own enterprise is expected by the service provider. The demand for innovations can be met by the service provider by an extension of its competence, only. Technological innovations – as e.g. RFID – are still pursued with great interest by the logistic management. Nevertheless, with the introduction of such new systems enterprises find themselves confronted with great challenges. It is true that many are well informed about the possibilities of RFID, but only a few have the necessary knowledge of the single potentials in their enterprise and of the right use regarding their needs.

Further Motives for Outsourcing of SCEM Services

Key Competences

A further aspect often mentioned is an enterprise's consciousness of its key competences. The concentration on the main components of an enterprise and the simultaneous purchase of foreign products therefore comprise the know-how of several experts so that the enterprise as well as the customer are profiting from the gained quality.

Innovation and Learning Effects

Outsourcing provides especially small- and medium-sized enterprises the opportunity to introduce technological innovations and release themselves from "old stock". Old stock means data processing or software systems which became obsolete, which cause high maintenance costs and the performance of which does no longer meet the current demands.

Personnel

Especially small- and medium-sized enterprises often have a loss of qualified personnel so that the outsourcing of a department means a profitable alternative. Furthermore, outsourcing for instance provides the opportunity to reduce the IT departments and to carry out only the necessary interface coordination by own personnel. This will reduce wage costs.

Disadvantages of Outsourcing

Dependence

The outsourcing decision being irreversible for a certain period of time, in the outsourced department the enterprise becomes dependent on the outsourcer. So, one is not only dependent on the top-quality delivery in time, but also on the possible insolvency or monopoly position of the outsourcing partner. In the great number of outsourcing projects this dependence, only, is feared.

Loss of Know-How

Due to outsourcing internal knowledge is understandably lost. Only in special cases this should be a key competence or leading knowledge since with the loss of know-how the competitive advantage at the market can be lost. However, there are cases which - despite the loss of knowledge – suggest themselves for outsourcing.

In fact, the success for the long term will be thus guaranteed and other segments can be concentrated on or extended. Furthermore, it has to be considered that in the future the outsourcing partner could offer new knowledge/innovations only with extra costs. This situation should be covered by law before.

Planning and Quality Risks

Due to outsourcing an enterprise can loose the direct influence on the service to be provided and thus has to live with the possible imperfections as well as problems of the service provider. Nevertheless, the outsourced segment can find itself under competitive pressure on the free market this leading to a better bargaining position for the enterprise regarding orders. Furthermore, also the delivery times of the service provider can become a new risk since work now is subject to external influence.

Loss by Interaction

Also the requirements on the management can change by the outsourcing of a business segment. Where one had had direct influence on the staff in the past, has to act as a kind of mediating agent from now on. It is recommended to previously check the existing organizational structure for possible frictions or dispute within the system. Then a so-called interface manager who will be able to mediate between the segments and the outsourcing service provider should be engaged for the future cooperation.

Survey of the Advantages and Disadvantages resp. Targets and Risks

Weighing up the suitability of the outsourcing of an SCEM solution requires the weighing of various aspects.

Advantages/Targets

The following aspects are points in favour of outsourcing:

Costs:

- planned cost reduction
- conversion of fixed costs into variable costs
- improved cost transparency

Personnel:

- release of own IT department
- independence on manpower shortage
- special IT staff unneeded

Risk:

- reduction of risks due to growing technological development
- increase of data security (alternative computing centre)
- techniques for risks and possible danger settled by contract

Technology/Know-How:

- access to specific know-how
- use of up-to-date technologies

Disadvantages/Risks

An SCEM service to be established as outsourcing solution requires, however, critical consideration of:

Costs:

- non-recurring conversion costs
- indefinite cost calculation
- planned cost reduction not coming true

Personnel:

- problems of personnel policy and employment law
- in case of manpower transfer loss of key positions and their know-how

Technology:

- dependence on the technological development of the outsourcing partner
- unwanted exchange of knowledge on the market

Data Protection:

- security of confidential data
- loss of know-how

Central Integration Techniques

Outsourcing furthermore provides the opportunity to start from unique and homogeneous IT structures. This is a basic prerequisite for a working SCEM and a constant information chain along the logistic chain. Therefore, this paragraph mainly focuses on the software and information and communication technology (ICT) suitable for system design and warranting a trouble-free communication among all subsystems being part of the SCEM network. Here, XML and SOAP are looked on as basis and examined in connection regarding their applicability. For ICT the necessary characteristics of mobile end devices applicable in SCEM processes will be shown. RFID as an identification medium with growing importance for SCEM is not dealt with in detail here.

Basic Examination of Integration Technologies

Basically the following paragraph deals with the suitability of different software technologies and hardware components in the fields of data keeping and data communication. Especially the aspect of platform independence is of central importance since the integration of most different software systems created on different hardware platforms positioned isolated from each other and of different software architectures in a higher SCEM can only thus be successful. Additionally to that the integration of the internet as currently most important communication network nowadays rather necessarily results. Besides that a continuous and real-time information status has to be absolutely warranted by mobile end devices and identification media since otherwise appropriate reactions by the SCEM control level cannot be effected or cause wrong consequences due to wrong assumptions. For the integration technologies looked on, i.e. software and ICT, this means that they have to provide a high degree of standardization, distribution and acceptance and of the quality of the transformation into programming languages as well.

Use of the XML Technology for Data Transmission

The evaluation of an inquiry of users and developers in the field of tracking&tracing by the Fraunhofer-Institut für Materialfluss und Logistik (IML) in Dortmund (Germany) showed that the eXtensible Markup Language (XML) is already applied by most of the enterprises and took the place of the classic forms of data structuring. Through it the spreading of the EDIFACT variant in that segment meanwhile became considerably less. In the face of these results the data structuring for an integration mechanism, in the form as necessary for a working SCEM, should be carried out on the basis of the XML technology.

XML can rely on a wide and above all an international support and therefore has been introduced along a wide front in all relevant programming languages at all relevant operating systems.

Advantages of XML in Comparison with Other Data Formats

XML was designed as general structuring language for the worldwide application in the internet. The strict definition of the XML syntax allows a simplified machine processing compared with less defined structures. Furthermore the explicit recording of the standards and regulations a document is based on supports a use in the international data traffic since country-specific units and regulations as well as the used font can be considered.

The possibility of structuring of data at simultaneous openness in the design of the describing structures is one of the essential advantages of XML. Additionally XML is easily readable for a human observer and logically understandable. Due to great number of tools it is also flexible in its application and handling.

Basic Principle of XML

The basic idea behind the XML technology is the strict separation of content, structure and representation (W3Consortium 2004). So it is possible to use an XML document for the storage or the exchange of data, whereas a corresponding XSD document determines the compulsory rules on the structure of XML documents of the same kind according to that the content of a particular XML document can be checked for well-structured ness.

Another file, an XSLT document defines the representation of a corresponding XML document in form of a scheme abstracted from definite content. There is a great number of basic document declarations open to the public existing in so-called „repositories“ which can be directly integrated. However, it has to be taken into consideration that those often – unlike to EDIFACT – are not worldwide unique, (UN-) standardized determinations.

The figure demonstrates this correlation by an example. A shipping order “order 0815.xml“ - type “shipping_order_domestic.xsd“ should be formatted according to „shipping_order_mobile.xslt“ to enable a space-saving representation of the order on a mobile end device.

Here the structure definition is realized within XSD and XSLT documents according to the same language constructs defined in XML standard so that for each of these files the same program logic can be used to evaluate the structures.

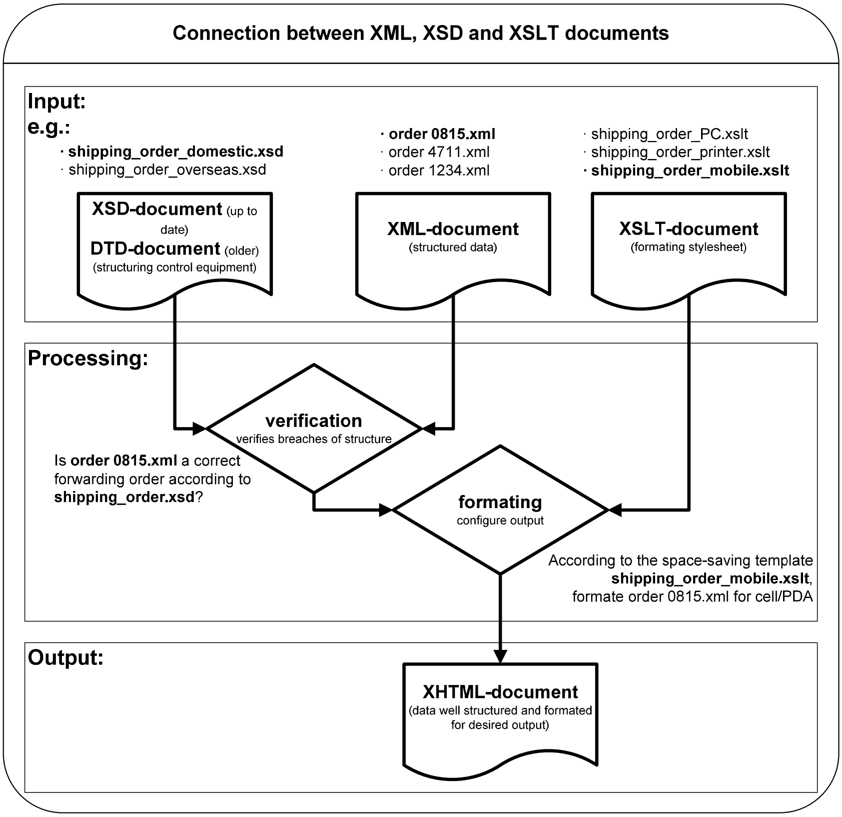

Fig. 1. Example for XML, XSD and XSLT documents and their correlation (Bonn a. Kraft 2006).

Specific Aspects of XML Regarding Tracking&Tracing

The importance of XML regarding tracking&tracing is clearly dealt with by Ulrich Assmann (Assmann 2004). He describes the business process integration with XML either in the temporal context as successor of the classic formats for electronic data exchange and in its importance for the currently continuing development. So the difficulties themselves in the development of data exchange formats are to be found in the correct modelling of the business logic and the adjustment of definite identificators. This is verified by the experience in the long development of enterprise-internal, over inter-enterprise formats up to a worldwide accepted standard as UN/EDIFACT. Due to its complexity this standard required the derivation of industry-specific subsets to keep the topic controllable.

Among the continuously changing demands on the modelling of business processes XML has already taken over the leading role. However, with XML also a paradigm change took place from the time-consuming global standardization towards the accelerated development of lean and bilateral influences of subjugated implementations. Assmann verifies this by a great number of diverging XSD schemes to the term ORDER in the usual internet repositories.

Therefore, efforts for standardization appeared again which mainly present themselves in two categories. Manifold attempts of a new original/independent model of the business process logic with foreseeable low market penetration are facing few successful 1:1-models of the established formats in form of the so-called XML wrapping. Assmann verifies this by the examples of the German Standard DIN 16557-4 as derivation of the EANCOM EDIFACT subsets and the SAP variant of the XML wrapping for IDOC messages. The strengths of these are shown in the applicability of the extensive “XML tools and workflows for structures introduced and tested by content“. From that Assmann infers that XML – besides process analysis and design – will become an important success factor with regard to the integration of business processes. So the processes can be rapidly and correctly modelled, and thanks to the web services based on internet technology also be realized free from proprietary communication infrastructure.

Basic Functional Principle of SOAP

The SOAP technology (Simple Object Access Protocol) is a method for inter-process communication on XML basis. As communication protocol for web services in distributed systems - being platform-independent and completely based on international standards, i.e. for the transfer of relevant information relying on XML documents - SOAP has found a wide spreading. SOAP thus directly starts on the basis of the XML technology. Compared with other RPC technologies, e. g. OLE, DCOM, ActiveX or CORBA, it provides a programming language and operating system independence. It therefore agrees with the demand of the application of an RPC technology independent from programming languages, operating systems and platforms, and available free from licence fees. In the inter-process communication SOAP knows synchronous and asynchronous communication forms which are realized by the use of appropriate basic channels. A method call made by an SOAP client is set into an XML-conform SOAP syntax - with method name and a list of parameters – and transmitted by HTTP request. An HTTP response is then transmitting the corresponding answer from the SOAP server.

In case of the synchronous communication with SOAP it has to be taken into consideration that it is susceptible to interference by connection breakdowns since the component is waiting for an answer. In case of the exchange of messages in asynchronous form the asking component can, however, continue its work due to the loose coupling of the two components. Nevertheless, an additional module would be required for recognizing and removing of message losses and in consequence an extensive programming.

Mobile End Devices in SCEM Processes

The single components of mobile end devices and the interaction of these components are described against the background that they interact with each other in the SCEM context. Then types of devices are introduced which have the functionality required in principle for these components and being of interest for the use within SCEM. Explicit characteristics will be shown and the advantages and disadvantages will be mentioned. Finally a recommendation will be given on the basis of the previously discussed suitability which mobile end devices are suitable for an SCEM.

Object Structure of the Mobile Communication-based Telematics

The figure "Object structure of mobile communication-based telematics" shows the simplified structure of the hardware components and their interactions integrated in a typical SCEM process.

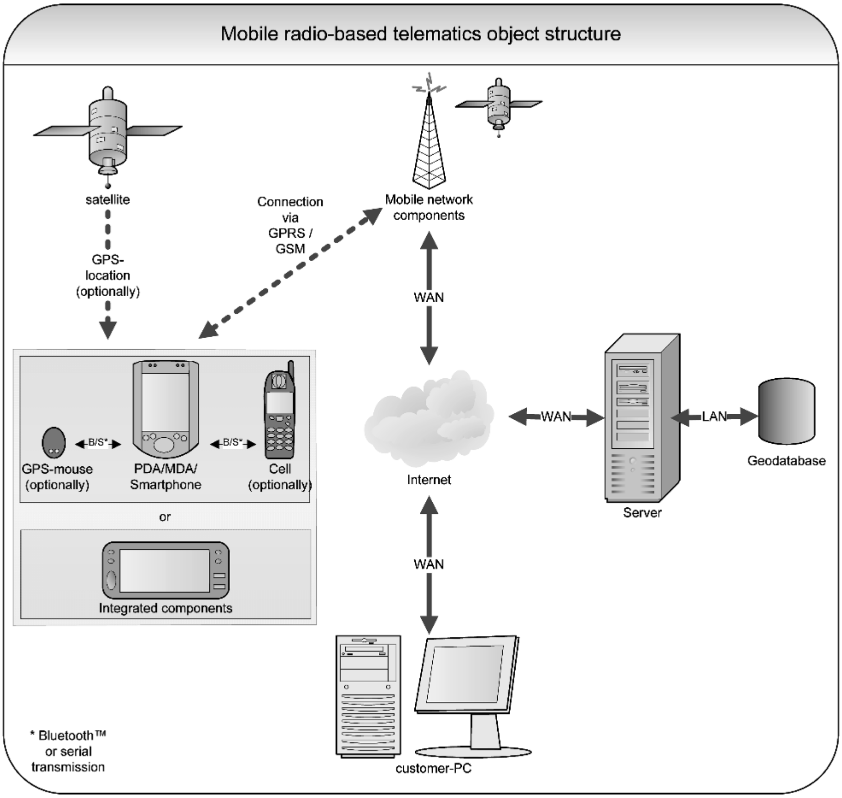

Fig. 2. Object structure of the mobile communication-based telematics.

Those mobile end devices especially marked by a frame are needed one each per mobile unit to be equipped. The functionality can be realized by two ways in principle: as combination of linked single devices from the consumer segment or as a mobile end device (MDE or specific PDA) composed of several integrated components and especially developed for the requirements of telematics.

The communication demonstrated by the figure is effected wireless between mobile end devices and their surrounding mobile communication infrastructure as well as conduction-bound via internet or local network structures.

The locating coarsely outlined here is done by the evaluation of the signal durations of the received signals of a number of GPS satellites sufficient for a position determination. The derived position is then sent together with the order-related data.

Assessment Criteria for Mobile End Devices

General assessment criteria of hardware are:

- basic functionality of the system
- sensitiveness to external influence (dirt, humidity, shock) and manufacturing class (protective class)
- design (standard size, external components)
- temperature-sensitiveness
- power supply
- external recording interfaces
- expandability of the end device within design
- storage capacity and storage media
- access security when interactive I&C end devices accessible from outside are used
- ergonomic design of user surface
- purchasing and operating costs

The devices have to provide the opportunity of an integrated or easily linkable data communication. The coupling of mobile phones and PDAs, e.g. on pocket PC or WindowsCE base, make communication and the visual representation of data and process flows available to the customer. Equipped with appropriate software PDAs furthermore provide the opportunity of the application of route planners or similar added value services und thus an extended functionality.

A completely integrated solution has, compared to this, certain advantages and disadvantages. The omission of the configuration for communication of the end device components leads among others to a considerably improved handling, the integration of all needed elements into an end device, however, necessitates a lower flexibility since the existence of many modules in the device also results in a higher purchasing price. Advantages of the integrated devices usually are a casing of industrial quality and improved ergonomic design by an enlarged display, e.g. compared with a smart phone. Modules as GPS receivers, barcode or transponder scanners, auditive communication via GSM and data communication via GPRS can be used together in one system unit.

In the following the most important types of devices or components will be described (Bonn a. Kraft 2006):

PDA Devices

PDAs (personal digital assistant) are offered today with a broad functional spectrum by a multitude of manufacturers. Two development lines are ruling the market: Pocket-PC-based and Palm-based systems. Palm-based systems are using the Palm-OS operating system family. The pocket-PC-based ones are using the WindowsCE operating system by Microsoft with the pocket PC operating system extension. These devices provide a communication with other components (e.g. connection to a mobile phone or a GPS receiver) on the basis of Bluetooth™ or via specific cable-bound interfaces. During running operation the cable connections here are subject to waer and tear to a certain extent only due to handling. The Bluetooth™ connection increases the handling time, because the radio contact has to be established before operation and again after each starting-up of one of the devices. The application of a docking station for the PDA provides a more reliable handling and durability since the connections are automatically made by inserting. Due to the PDAs tailored as consumer products the respective components are, however, in general subject to increased wear and tear.

Continuous innovations in the field of the consumer PDAs let expect a more frequent change of device than in case of a device of industrial quality. The consequence is growing equipment in combination with decreasing prices, but vice versa also a limited compatibility either for hard- and for software. There are, however, versatile extensions as protective hoods, additional accumulators, memory cards, and also card-reading devices, barcode scanners and keyboards providing added value for several applications.

Mobile Phones/Smart Phones

Meanwhile the GPRS and UMTS mobile radio standards have an adequate and area-wide reach ability. So the user is made available technologies which, due to their concept, are suitable for connecting the mobile units to SCEM. Due to the GPRS data throughput for data to be recorded by an application in SCEM can be classified as sufficient and that, in case of doubt, currently GPRS still being the fall-back level for UMTS in case of missing coverage it is recommended to fall back on mobile communication units or mobile phones based on GPRS. In case of higher-value information processed – e.g. images – UMTS is recommended.

When using mobile phones it has to be mentioned that those cannot adequately be used as pure data transmission component so that at last all tasks of mobile communication can be carried out with the aid of this one component in the near future without using e.g. an additional PDA. If ergonomic aspects, however, will be taken into consideration here is absolutely questionable. So, a mobile phone with typically very small display and operating elements closely arranged to each other is very specifically tailored for its application. The facility for extension is also only provided by the connection of separate components with additional own power supply, each.

Locating Components

Locating modules or – according to current state of the art - mostly GPS modules can be purchased as standard components today. The connection is made via an interface - e. g. serial cable, infrared or Bluetooth – to an appropriate device for further processing or transmission of the position data. The technical connection can, e. g. have the following characteristics:

- integrated, i. e. the GPS module is firmly built in another component
- cable-bound – the GPS module is connected to another component by a cable
- transmission by Bluetooth™, i. e. a Bluetooth™ module integrated in the GPS module can communicate with another Bluetooth™ module - e. g. in a PDA or mobile phone – by short-distance radio

To meet the demands of future with the system design of SCEM it should be taken into consideration how far a use of Galileo will be possible in a later extension or developing phase.

Integrated End Devices

The class of the integrated end devices unites the functionalities of auditive and data communication, user interaction via a big touch-sensitive display, GPS location, accu with an application time of a minimum of eight hours, industry-quality casing as well as further components as barcode readers, transponder readers, WLAN or Bluetooth™. Currently the market for these devices is very heterogeneous. This means that many manufacturer-specific hardware and operating system combinations with, in parts, very different programming opportunities exist.

Mobile end devices of this kind are meanwhile available in great versatility as universal end devices with applications providing high computing performance, mobile communication, locating and identification by barcode, image identification or RFID. Characteristics making these devices advantageous is that they are optimized for industrial processes, e.g. in warehouses or within near-distance transport by forwarders. Due to the integration of the mentioned logistic-relevant functions (barcode scanner, GPS) it is possible to use a telematics end device with all relevant functions for SCEM. A great part of the technical error potentials in the coupling of single components can be avoided here by the high degree of integration. For this class of devices the rapid technical development and thus the dependence on hardware and operating system deliverers has to be more considered.

Result of the Hardware Components' Assessment

The class of PDAs provides a good compromise between price and performance, does, however, burden the user with increased handling time, remaining stability problems in the operating system and a weak accu operating time in case of the use of the device becoming necessary outside a loading frame. A device either integrating computing unit, GSM/GPRS module and also GPS receiver is superior to a combination solution by reliability, handling and durability.

Realization, therefore, has to clearly focus on the use of an integrated end device. The general functionality nevertheless will also be warranted under limited ergonomic aspects by a PDA-based combination solution.

Summary

Various studies showed that the need of standardizations in the field of SCEM is considerable because several problems still being an investment hindrance would thus be solved at once. For example, outsourcing of an SCEM solution would reduce the starting investment, and standardization would allow the transporters and other protagonists of the supply chain the use of the components in changing surroundings.

Findings Regarding the SOAP and XML Integration in Connection with SCEM

The essential finding of the examination of the available integration technologies directly corresponds with the initially mentioned requirement analysis. The XML technology is completely established, obvious by its wide utilization as well as by the broad support of operation systems and programming languages and has already attained a nearly absolute market penetration. Using XML style sheets XML attains a quality unknown from classic EDI formats and thus being superior. Important is, however, to be aware of the choice of XML solely being the technical part of the solution and to recognize the more essential part in the importance of the thorough process analysis and design in the modelling of business processes. It is therefore recommendable to accept the business logic, the ident terms and the message type definitions as 1:1 image known as XML wrapping. In this context XML is a proven and future-orientated choice as well.

In the face of the orientation on the XML technology the integration of SOAP will be the next logic step because SOAP as currently top variant of an RPC protocol is based on XML as well as promising synergy effects in the common use with XML. The clear integration of the internet and the flexibility of the web services made with SOAP represent considerable advantages of this technology, the almost total platform independence featuring nearly sole position. This is proved by the success of SOAP web services at providers as Amazon and Ebay thus extending existing and gaining new market shares.

Findings Regarding the Evaluated Variants of Mobile End Devices

The examination of the applicable hardware of mobile end devices showed that especially the integration of single functional components in an end device is meeting the specific requirements on ergonomy and operating safety. The interaction of the modules for GPS-based location, GPRS or UMTS communication and extensions as barcode or transponder scanners can thus directly warranted without the time-consuming handling of cables or radio connections. This allows to gain all information required for SCEM flexibly and in a mobile way. For the application in SCEM-assisted processes end devices of industry quality with larger, touch-sensitive display and robust design may be preferred to consumer devices despite higher costs.

Results

Changed markets and harder competitive conditions become new challenges for the enterprises which have to respond to changes by efficient process structures. Promising concepts will be made available within the frame of the abovementioned supply chain management by which the integrated process-orientated planning and control of the goods, information and money flows along the entire value added chain from the supplier of raw materials up to the customer is to be understood. The IT systems until now used for the control of the supply chain within an enterprise mostly are component of a heterogeneous system world and due to incompatibility hide red to exchange the required data among each other, this leading to a considerable decrease of profitability and effectiveness. Only a standardized system would link the enterprises (forwarder, client, service provider, etc.) with each other and thus attaining a successful, improved process within the complete structure. In this point outsourcing comes to the fore. It provides the opportunity to make use of a standardized (homogenous) system which outsources and standardizes the logistic segment and thus delivering the wanted effectiveness. Currently, however, many different solutions are available due to which the process structure is considerably suffering from and resources unnecessarily being consumed. Furthermore, the enterprise is then able to concentrate on the key segments and thus no longer occupied with the management and transport of the goods. In summary, one can say that – with regard to SCEM – especially outsourcing is an important factor for the future of an enterprise to compete on the current as well as on the future market. Only such standardizations of new technologies make the complex and versatile world of logistics more attractive for enterprises.

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Holistic and Pragmatic Approach on Proactive Supply Chain Event Management

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Introduction

Automotive OEM's are faced with ever increasing cost pressures, particularly in the established markets of North America and Europe. This is a result of rising competition, high labor cost and shrinking profit margins.

In times of strong competition, every automotive company is looking for cost reductions in all fields of the value chain to stay competitive. One area of opportunity is in Material Cost Reduction (MCR). MCR can be achieved by utilizing multiple methods and analysis tools including total landed cost, linear performance pricing models and low cost country sourcing. The selection of the correct method or tool is integral for the achievement of MCR. For specific commodities, such as grab handles, sun visors and electronic components, Low Cost Country Sourcing may be an ideal solution.

The selection of suppliers and supplier locations in Eastern Europe and East Asia has become increasingly important due to lower labor costs. One example of this solution can be found in the advancement of General Motors purchasing volume in Romania, which will increase from € 550 million in 2006 to € 1 billion by 2010. In addition, GM sourcing activities in Turkey over the same period will soar to € 500 million from € 150 million (Source: Automotive News, April 2nd 2007).

The results of these low cost country sourcing activities are global supply chains. It is now possible to have a supply chain with an Automotive OEM location in Germany, a Tier-1 supplier in India, with Tier-2 suppliers' locations in South Africa, Eastern Europe and South East Asia which creates a complex chain of interdependent companies that spans the globe. For the existing OEM assembly plants in Western Europe or North America global supply chains lead to four main challenges:

1) Handling increased complexity in supply chains
2) Improving supplier collaboration

3) Creating supply chain stability
4) Overcoming cultural and bureaucratic barriers

The impact of increasing product complexity, volume fluctuations and production mix must be considered in the planning and design of cross regional supply chains. Managing these factors through the integration of capacity planning, demand management/volume forecasting and level production scheduling can lower the risks involved with the inherent supply chain complexity.

Improving the level of supplier collaboration is becoming more important since the increased prominence of global supply chains. A large supply chain tends to be less agile, therefore, the ability of the Tier-1 through Tier-N supplier allows greater manufacturing flexibility for the OEM to have low production lead times. Tier-1 Supplier integration and collaboration within the entire supply chain network is also being enhanced by the quick data exchange possibilities of the internet through advents such as EDI and email.

Supply chain stability is an additional challenge for the global management of supply chains. First, careful demand and capacity planning must be mentioned, but also the development of contingency concepts is necessary to avoid expensive problems in supplying production. The correct level of finished goods on hand while maintaining a lean operation is critical to the success of all involved parties in the supply chain.

These challenges are supplemented by the difficulties in working with different countries around the globe. Diverse behaviors, languages and customs often result in issues such as miscommunication and poor data integrity which lead to overall inefficiencies. Government regulations and laws that differ from country to country can also create an extra layer of bottlenecks to the supply chain if not fully understood and followed.

Managing global supply chains poses a great challenge for supply chain management professionals. If it is not possible to find sufficient solutions for these issues problems with the parts supply for OEM production may occur, ultimately resulting in a work/production stop. One possibility to cope with these challenges would be to hold higher inventory levels in each step of the supply chain, but this would lead to higher costs, problems in product change management and a lower utilization of resources. The MBtech approach to avoid a work/production stop due to global supply chains is described in the subsequent article.

MBtech Consulting Approach

The MBtech approach to avoid a work/production stop due to global supply chains follows the established three step approach of MBtech Consulting:

1) Supply Chain Visualization & Risk Assessment
2) Supply Chain Design or Optimization
3) Supply Chain Performance Measurement & Event Management

This holistic approach leads to a global Supply Chain Design & Optimization from the OEM to its Tear-n, with stable and secured processes from the beginning of the planning process. The outcome is a supply chain design that benefits all parties and promotes a close collaboration between the OEM and its suppliers throughout the complete process.

Supply Chain Visualization & Risk Assessment

As a first step of this process it is important to have an overview of the global supply chain from the OEM to its Tier-n suppliers. Following the Value Stream Mapping approach a detailed Supply Chain Visualization must be created incorporating all involved supply chain parties to surface data that includes:

- Supplier Location
- Product
- Product flow
- Order mode and lead time
- Process times
- Inventory levels
- Batch sizes
- Delivery frequency
- Transit times
- Packaging / Load Carriers

Once the Supply Chain Visualization is complete, potential risk identification is compiled as a first step in the Supply Chain Risk Assessment. Some potential risks that can occur between each tier level are:

- Financial Risks (e.g. currency fluctuation, insolvency)
- Logistics Risks (e.g. delays, customs duties)
- Engineering Risks (e.g. testing failures, R&D expenditure)
- Force Majeure (e.g. strike, terrorism)
- Operations and Quality Risks (e.g. IT-failure, quality issues)
- Procurement Risks (e.g. price increase)

Risk Identification is followed by a Risk Analysis and Evaluation, which includes a risk incident occurrence probability and the impact of a potential risk incident. The combined evaluation of both analyses results in a Risk Documentation that highlights potential risk gaps prioritizes potential risks and identifies high-risk supply chain partners.

A committed Supply Chain Visualization and a Risk Documentation are the result of this first step. The insights derived from these deliverables are the base for the following step, the Supply Chain Design or Optimization.

Supply Chain Design or Optimization

The following Supply Chain Design or Optimization should be geared to an optimization regarding cost, time and quality, with a focus on the reduction of all identified risks. This type of planning assures an operational implementation which is economical and has low risk potential.

The mentioned Supply Chain Optimization targets (economical and low risk) compete against each other, so the planning results will not achieve all targets likewise. For example, an optimization concerning quality exclusively would lead to higher costs; this is why targets must be prioritized to find the right balance between time, cost and quality. Overall the main target should be a cost reduction, followed by the best reachable quality with short lead times in all processes. The optimization of a supply chain can be performed in four main areas:

1) Logistics
2) Procurement
3) Engineering
4) Value-Add

Logistics optimization is an improvement of the transportation through increased capacity utilization; an example would be to implement a milk-run instead of many LTL's. Besides milk-runs the optimization of warehousing, the trailer yard concept, just-in-sequence delivery and packaging density and quality are useful areas of optimization.

Procurement professionals depend on stable supply chains and they can use techniques such as bundling purchasing volumes which can be applied to purchasing raw materials as well as transportation services to ensure a steady supply. Also, the early identification of high risk suppliers could lead to changes in the supply base that reduce overall supply risk.

Additionally, engineering's actions have a large impact on the supply chain; complexity reduction and design standardization are common examples of reducing pressure through engineering. Furthermore, the design-to-logistics approach is a helpful method to proactively reduce logistics costs.

As a last area the value-add actions can be optimized through not only understanding which processes should be performed but where they should take place. The first step is to identify which process steps are value-add and which are not; the non-value add steps should be eliminated if possible while the value-add steps should be organized to follow a logical order. The second step in value-add analysis is to optimize the location of value-add steps. Some suppliers have competitive advantages and are cost beneficial in only half of the value-add steps they perform; in this case the value-add steps that they do not specialize in should be moved, if possible, either in-house or to another supplier who does specialize in those areas.

After a supply chain is optimized in the four areas of logistics, procurement, engineering and value-add the sum of the remaining risk probabilities should be no greater than 20%. If the feasibility is still higher measures must be defined in order to reduce the risk probability. This could lead to increased costs during the launch phase, but it is necessary for a successful operational implementation. Our experience shows that from a total cost standpoint it is much more cost effective to pay more for a safe process in the beginning, than saving money at first and having the high costs of globally expedited shipments to ensure steady supply.

An optimized supply chain regarding cost, time and quality incorporating the outcomes of the Supply Chain Risk Assessment is the result of step two.

Supply Chain Performance Measurement and Event Management

A specific performance measurement tool has been developed by MBtech Consulting to implement an operational Supply Chain Controlling and Event Management project. Measuring pre-defined key performance indicators can be used to reflect the critical success factors of the supply chain processes. The measurement can also assess the present efficiency of these processes and prescribe a course of action for further improvement. The MBtech Consulting Supply Chain Performance Measurement approach is a combination of the following established models and indexes (Fig. 1):

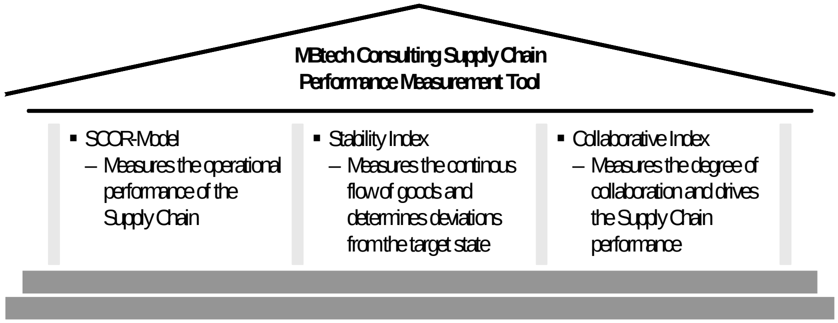

Fig. 1. MBtech Consulting supply chain performance measurement tool

1. **SCOR-Model (Supply Chain Operations Reference Model):** The SCOR-Model is the basis for this supply chain performance evaluation tool due to its practical development and its wide acceptance among companies. A significant part of this tool is the integration of the adapted collaborative index and a newly created stability index with the SCOR-Model. This extensive tool ensures a holistic Supply Chain Performance Measurement by analyzing the five key performance attributes of a supply chain: reliability, responsiveness, flexibility, costs and asset management efficiency. Due to the fact that implementation of the SCOR-Model is a complex and time-intensive procedure, its full implementation and use is not possible within the restricted time of most projects. For this purpose the SCOR-Model is streamlined and tailored for a quick supply chain assessment for one particular commodity group. Ta-

ble 1 provides explanations and describes the metrics for the main performance attributes.

Table 1. SCOR metrics classification

Performance Attribute	Performance Attribute Definition	Metric
Supply Chain Delivery Reliability (DR)	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.	Delivery Performance Fill Rates Perfect Order Fulfillment
Supply Chain Responsiveness (R)	The velocity at which a supply chain provides products to the customer.	Order Fulfillment Lead Times
Supply Chain Flexibility (F)	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Supply Chain Response Time Production Flexibility
Supply Chain Costs (C)	The costs associated with operating the supply chain.	Total Supply Chain Management Costs Value-Added Productivity Warranty/Returns Processing Costs
Supply Chain Asset Management Efficiency (AM)	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-Cash Cycle Time Inventory Days of Supply Asset Turns

2. **Collaborative Index:** The Collaborative Index (CI) has been adapted to create a strategic link to steer the operational performance of a supply chain. Through the measurement of the degree of collaboration between supply chain partners a statement of the future operational performance can be derived. The three measured areas within the CI are:

   1) Incentive Alignment
   2) Decision Synchronization
   3) Information Sharing

   The three measured areas of the CI are enablers of supply chain performance. The CI points, unlike the SCOR model, at a supply chain's potential and not at the current performance; therefore, a prediction about the future performance can be completed with the results of the CI. Poor or even good performance at the expense of a company's mid to long-term performance can and should be precluded through the measuring of the collaboration.

   The data collection of these intangible factors should be conducted through a questionnaire, in which the assessed company must rank a given statement by its agreement or disagreement. The following Table 2 shows an extract of the full questionnaire for the collaborative index:

Table 2. Extract of the collaborative index questionnaire. Response scale: 6 = strongly agree; 5 = mostly agree; 4 = somewhat agree; 3 = somewhat disagree; 2 = mostly disagree; 1 = strongly disagree

	6	5	4	3	2	1
Information Sharing						
The information provided in current plans and schedules focuses on the most useful metrics in the appropriate detail.						
The departments in my supply chain simply use the plans and forecasts provided, without needing to reformat them.						
My company has direct access to all the data it needs from supply chain partners for effective planning.						
My company informs the customer immediately if possible supply disruptions are about to occur.						
Decision Synchronization						
Opportunities for improvement are regularly discussed with my partners along the SC.						
The potential of our suppliers are fully used early in the product development process.						
We regularly measure and improve supply chain performance between the partners.						
We regularly search for opportunities to improve the supply chain.						
Incentive Alignment						
We get support when performance problems are occurring.						
We share benefit gained from a supplier's/customer's cost-cutting proposal with them.						
The risk if the demand forecast drops is carried mutually by the partners.						
The incentive alignment (sharing costs, risks, and benefits) motivates involved parties to optimize the overall supply chain instead of parts of it.						

3. **Stability Index:** This Stability Index (SI) is restricted to controlling supply risk, which can be defined as potential or actual disturbances of the upstream product or information flow. The steady growth of global supply chains increases supply risks, therefore, the SI was created to provide information on the robustness of a global supply chain while measuring and controlling logistical risks. Through the development and the integration of a SI the smooth and stable flow of material, information and finance can be tracked and measured while the results of this index can give a prediction of future disruptions. In particular for the automobile industry where the cost of a supply chain disruption is high, supply chain stability is an important measure. The SI is considered to be part of a Supply Chain Event Management (SCEM) system; a characteristic of these SCEM systems is that they recognize when a target is not fulfilled. But SCEM systems do not identify root causes of problems, whereas the SI as used in this approach detects performance gaps or changes and alerts before a disruption occurs. Through the combination of the SCOR

model, the CI and the derived dependencies between these metrics the SI addresses the sources of possible issues. In order to create the stability index, the characteristics of stable supply chains were investigated and the stability attributes are assessed either through the SCOR metrics or through the CI questionnaire. The SI does not require the gathering of data; it is an extraction and combination of the other metrics. The following attributes describe and impact the stability of supply chains:

- Visibility of inventory at all stages
- Knowing the consumption rate
- The anticipation of correct future inventory levels
- Quick response time
- The forecast time
- The perfect order fulfillment
- The volume and delivery flexibility

As an additional attribute, that stabilizes supply chains the inventory level must be mentioned. A high inventory level (finished, WIP and raw material) obscures problems in processes, but it secures the flow and prevents from breaks. A stabilizing of the supply chain through high inventory at the different stages is neither efficient nor desirable according to the 'lean' approach. On this account the lead-time within the 'Order Fulfillment Lead Time' metric that measures how long it takes from the customer order to delivery of the product is not considered for the SI. This would create wrong incentives for the persons involved and skew the data from the supplier. The result of this unique Supply Chain Performance Measurement and Event Management approach is a tool which highlights the strengths and weaknesses of the entire supply chain network. Based on this result a continuous improvement process as well as a proactive supplier risk assessment can be implemented if the performance indicators show that problems may occur in the near future.

Case Study

The developed approach was tested and developed in several Supply Chain Optimization projects. One project was focused on the supply chain of a major OEM located in Michigan, USA, which was receiving transmission control modules (TCM's) from a tier-1 supplier located in Germany**.** Using a three-step approach the supply chain evaluation and optimization project was carried-out:

1) Gather data
2) Identify optimization opportunities
3) Elaborate on optimization potentials

Gather Data

Before the collection of data through the questionnaires is conducted, it is necessary to get an overview of the supply chain and to document the basic information. The TCM was supplied to three different manufacturing locations for the OEM, one in Europe and two in North America; the plant in Europe was not considered in this project, only the shipments to the North American plants were of interest. Table 3 gives an overview of product and shipment specifications which was provided by the supplier's employees in its engineering and packaging departments.

Table 3. Product and shipment specifications

Part price/Currency Unit (CU)	69
Cubic volume per part/m^3	0.000352
Cubic volume per box incl. 34 parts/m^3	0.0193
Cubic volume per pallet incl. 12 boxes/m^3	0.3904
Weight per part/kg	0.21
Cubic volume per shipment (8 until 2007, 9 until 2010)/m^3	3.12/3.51
Weight per shipment/kg	720/806
Number of annual shipments	118/120/110/113/113

After the supplier provided information about his suppliers (i.e. tier 2-n), the supply chain map (Fig. 2) was created**.**

Later the performance of the supply chain was evaluated through the developed form. An interview with the Key Account Manager of the supplier was first carried out in order to explain the project and its aim, and also to get a first qualitative idea of supplier's way of managing supply chains; the key was to understand how the supplier looked at the importance of collaboration.

The manager then distributed the developed to the relevant persons and departments within the supplier's organization: the logistics planning, purchasing and financial departments in Germany and the sales department in the USA.

Afterwards, most information necessary to assess the operational performance (SCOR metrics) were provided by the Supplier. The results of the composite performance attributes are shown in table 4.

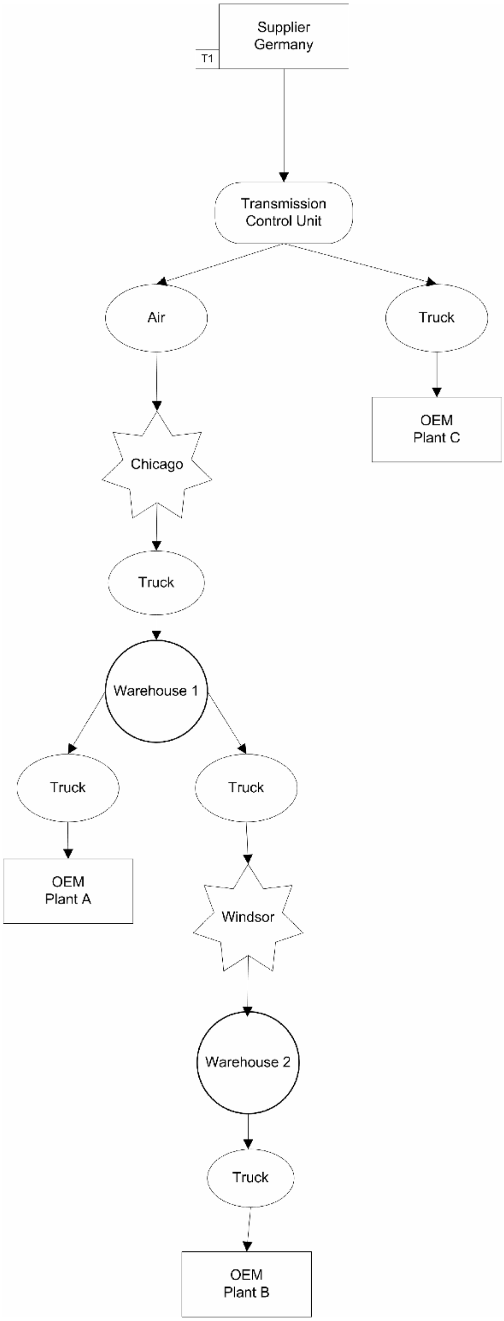

Fig. 2. Current supply chain map

Table 4. Supplier scorecard

Performance Attribute	Metrics	Measured
Delivery Reliability	Delivery Performance	99 %
	Fill Rates	89 %
	Perfect Order Fulfillment	95 %
Responsiveness	Order Fulfillment Lead Times	31 days
Flexibility	Delivery Flexibility	134 %
	Volume Flexibility	86 %
Costs	Cost of Goods sold	1,300,000 CU
	Total SCM Cost	5 %
	Value-Added Productivity	58.667 CU
	Warranty / Returns Processing Costs	0.4 %
Asset Management	Cash-to-Cash Cycle Time	32 days
	Inventory Days of Supply	42 days
	Asset Turns	5 days
Information Sharing		29 %
Decision Synchronization		29 %
Incentive Alignment		20 %
Stability		63 %

Identify Optimization Opportunities

The SCOR metrics and the following analysis highlighted two major opportunities for an optimization:

1) Improvement of the Collaboration between the supply chain parties
2) Reduction of the order fulfillment lead time

Through a detailed view on the forms it is noticeable that the results of the collaborative index are poor. The average rating for ‘information sharing’ and ‘decision synchronization’ was only 29% while ‘incentive alignment’ reached just 20%. The operational performance metrics which influenced the SI of this supply chain were good so a stable supply was guaranteed, but due to the poor collaborative results the SI reached a total of only 63%.

The stability is mostly achieved through the late decoupling point between the pull and the push system in which the OEM was pulling material from a warehouse while the supplier was pushing the goods into the warehouse.

The order fulfillment lead time of 31 days was deemed excessive while it is the calculated average of the deliveries to both North American plants. The delivery mode by air is optimal, but multiple handling stages increase the total lead time. As a result of the lengthy order fulfillment lead time the inventory days of supply, especially the finished product inventory was high.

Elaborate on Optimization Potentials

An improvement of the collaborative index is not a quick-win program; collaboration must be built and needs time and effort. For this reason the purpose of this project is to optimize the operational performance and to encourage the OEM and the supplier to think about ‘collaboration’.

Another aspect that is worth investigating is the actual need for the several handling stages; they are not adding value to the TCM, but only storing and consolidating the inventory. Re-modeling of a new delivery concept would be possible without impacting any production stages being that the focus is on removing non-value-adding steps. Without these non-value-adding stages the order fulfillment lead time would shorten drastically, resulting in lower inventory costs.

Removal of the non-value-adding steps required a change in the arrival location of the airplane. Direct delivery close to the plants is necessary to shorten the distance and time for ground transportation. Next to plants A (20 miles) and B (26 miles distance) are airports which are appropriate for the delivery to the plants.

The initial logistics cost from Germany to the two plants was 3.75 CU (the abbreviation CU will be used as the currency unit in this business case.) per part, this cost included transportation, duties, taxes, fees, etc. A quotation from a new service provider offered logistic costs of 0.95 CU to Plant B and 2.39 CU to Plant A. The new supply chain is shown in figure 3.

The difference of 1.44 CU between the delivery to plant A and plant B is caused by the tax of 2.6% of the part price that must be paid to import the TCM’s into the USA while an import to Canada is tax-free. Every fourth day eight pallets including 3,264 parts are delivered to each of the airports while the service provider operates a daily delivery between the airports and both plants. Table 5 shows the gained logistic cost savings.

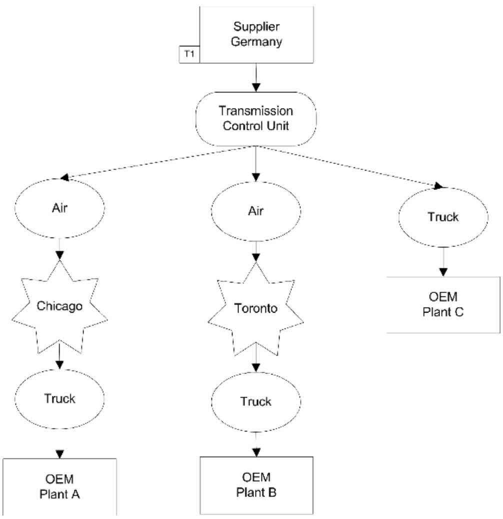

Fig. 3. Improved supply chain map

Table 5. Logistics savings per year (CU)

	Plant B	Plant A
Current logistic costs	750.000	750.000
New logistic costs	478.000	190.000
Savings per year	272.000	560.000

The order fulfillment lead time was reduced through the direct delivery concept by a reduction of the finished products inventory carried at the warehouses. The days of holding the inventory are averages; hence the two investigated supply chains are different. These savings are depicted in table 6.

Table 6. Finished product inventory savings per year

	Current concept	Proposed concept
Inventory holding factor/%	13	13
Finished product inventory/days	20	5
Current finished product inventory/CU	1,511,000	377,000
Current finished product inventory holding cost/ CU	196,000	49,000
Savings per year/CU		147,000

The supply chain performance measurement was a success for both the OEM and its Tier-1 supplier. Both now believe that they must strive for collaboration being that opportunities were identified which improved the supply chain and saved both parties money. Thanks to the change of the logistics service provider 832,000 CU can be saved per year while an additional 147,000 CU can be saved per year by the reduction of the inventory from 20 to 5 days, which will also lead to a reduced order fulfillment lead time from 31 to 10 days.

Lessons Learned

Following the MBtech Consulting approach for Supply Chain Event Management an early involvement of all supply chain parties helps to achieve the planning targets for time, cost and quality. In the best case scenario the collaboration should start in the strategy or concept phase of the OEM's Supply Chain Design process. The early Risk Assessment is also necessary to identify gaps and define measures to weaken the risks.

Furthermore, a strong collaboration in discussing opportunities with all supply chain parties during the Supply Chain Visualization and the evaluation of improvement potential is essential. This should follow the "Open book" philosophy, in which all supply chain parties are privy to integral supply chain information.

Finally a regular performance measurement must be implemented to control the entire supply chain. This allows a proactive Risk Management of the supply chain to be able to react as soon as possible when adverse events occur in product supply.

Key Message

Based on the described challenges a global Supply Chain Event Management follows a holistic three step approach taking into account:

1) Supply Chain Visualization and Risk Assessment
2) Supply Chain Design or Optimization
3) Supply Chain Performance Measurement & Event Management

The successful realization of this approach requires an early involvement of all supply chain parties in the approach and a strong collaboration between the OEM and its suppliers.

The measuring of supply chain performance, collaboration and stability (which has been neglected in the past) is not only important for the automotive industry, most industries deal with the same logistical challenges. As supply chains grow globally, the stable flow of product through supply chains will become more important in theory and practice.

Supply Chain Event Management (SCEM): A Strategic Application of Business Process Management (BPM)

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Introduction

This chapter describes the relationship between Business Process Management (BPM) and Supply Chain Event Management (SCEM). The basic message is that BPM is a prerequisite for SCEM and therefore SCEM can be seen as a strategic application of BPM. BPM is not only a technology, to the contrary it is a philosophy which is enabled by technology, assisting managers in its implementation. According to David McGoveran:

"BPM teaches that a business can be understood and managed solely in terms of business processes, and it teaches how to manage those business processes. It's process-centric, closed-loop and continuous design, change, monitoring, and control responsive to business requirements and objectives. Unlike Business Process Reengineering (BPR), BPM embraces how people actually work rather than forcing an ideal business process. BPM is mostly agnostic with respect to traditional management theories. " (McGoveran 2003)

Another definition made by Rashid Khan introduces the technological level:

"BPM is the discipline of modelling, automating, managing, and optimizing business processes to increase profitability." (Khan 2003)

This columnist also introduces the concept of business process and breaks it down, making it quite comprehensible and establishing some relations to BPM tools: A business process is defined as, "A sequence of structured or semi-structured tasks performed in a series or in parallel by two or more individuals to reach a common goal." The five essential points in this definition are:

- A business process consists of a sequence of tasks. One task alone, performed by one person, isn't a business process. With BPM, simply modelling the process can help you identify tasks that can be eliminated or automated for dramatic improvements.

- A business process is structured or semi-structured. This means there's some logic or rules that dictate the sequence in which tasks occur. They're not performed on an ad hoc basis. When there's a clearly defined logic, automation can eliminate errors and make decisions on routing.

- The tasks can occur in a **series or in parallel**. Most tasks follow sequential steps from beginning to end. These types of tasks are reasonably simple to automate and track. However, it's often hard to perform tasks in parallel where two or more actions are happening simultaneously without some form of automation and tracking mechanism. With BPM, parallel routing is easier, but you can also always know where a particular process incident is in its life cycle, who is working on it now (or should be), and where it will go next.

- There must be at least **two or more individuals** or applications involved as players performing different tasks in the workflow. As information flows from person to person, the possibility of losing something, making an error, or interpreting it incorrectly increases. Automating steps and capturing information electronically lowers the likelihood of such errors. If applications are involved in the process, having the information already in an electronic format simplifies integration.

- The sequence of tasks must have the purpose of reaching **a common goal or outcome**. Business processes are geared toward producing results. By applying the discipline of BPM, you can focus on the desired results and measure your execution against that standard. If you're not meeting goals, optimization can be used to improve performance. You have a real, tangible opportunity to improve business process execution.

It is clear that BPM tools assist managers on implementing the BPM philosophy making business processes more visible, comprehensible and measurable. Moreover, the description of the processes includes the different resources that take part in the process enabling to balance those processes, consequently, optimization is given.

The Acceptance of BPM in Industries

BPM is vital to the entire supply chain management and the logistics side of the industries are asking to be provided with these. For “outsiders”, however, it can be a scary tool. A business partner not used to meters upon meters of printed paper will be disoriented and quickly frustrated, as following a BPM is not exactly an easy thing to do. BPM is a methodology which needs to be administered in a very careful and easy to swallow portions for onlookers not involved in BPM on a day to day basis. There are some strict and good rules for mapping and these should be adhered to for the sake of the project and the people involved.

Supply Chain Management (SCM) and Supply Chain Event Management (SCEM)

We understand supply chain as: “the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer” (Christopher 1998).

Secondly, the management of the above concept: “The supply chain management is the management of upstream and downstream relationships with suppliers and the customers to deliver superior customer value at less cost to the supply chain as a whole” (Christopher 1998).

Thirdly, we will consider that the above philosophy is about the known functional area of logistics, which is defined as follows:

“Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that future profitability is maximized through the cost-effective fulfilment of orders” (Christopher 1998).

The concept of supply chain management points out the necessity of companies coordinating their logistics function in order to gain a global view of the value chain. As a result of these joint efforts a gradual improvement takes place in the supply chain.

Supply Chain Event Management can be described as the 'watchdog' of SCM. With some more detailed discussion later in this article, it concentrates on aspects like tracking and tracing and adds functionality like alerting to the supply chain processes. Therefore, SCEM enhances steering and decision support mechanisms of SCM.

Business Process Management and Supply Chain Management

When we talk about BPM, we directly think about processes. In the same way, it is not possible to talk about SCM and not mentioning the word process. Increasingly, when managers talk about the alignment between business processes, goals, IS applications and middleware systems, they rely on an enterprise architecture to define how the business-IS alignment should be achieved.

Today, there is a growing movement among both business managers and IS managers to use the term “enterprise architecture” to refer to a comprehensive description of all of the key elements and relationships that make up an organization

(Harmon 2003). Recently, one of the most frequently discussed architectural models is the Service Oriented Architecture (SOA).

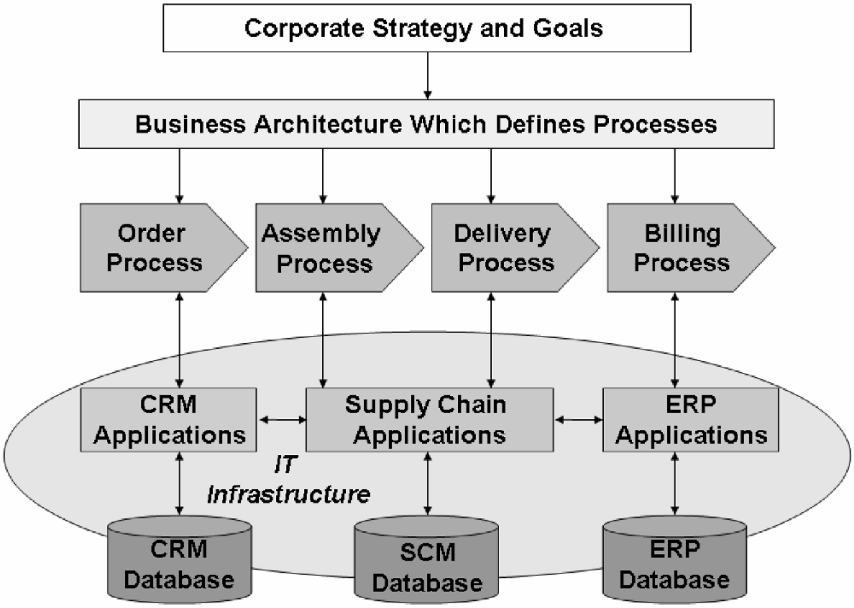

Fig. 1. Aligning processes, applications and databases

In figure 1, some supply chain management processes are shown from the "enterprise architecture" point of view. Consequently, a clear definition of end to end processes is a core issue for the SCM function. BPM tools can assist managers in the definition and integration of SCM by introducing a broad range of SCM processes (see also picture below), for instance (Grudén a. Strannegard 2003):

- In sourcing, forecasting, and planning in collaboration with suppliers
- In manufacturing and logistics between different suppliers in a project
- In the planning and visibility of sales and distribution in collaboration with retailers, vendors, and distributors.
- In the coordination of after-sales service between retailers, vendors, and contract manufacturers.

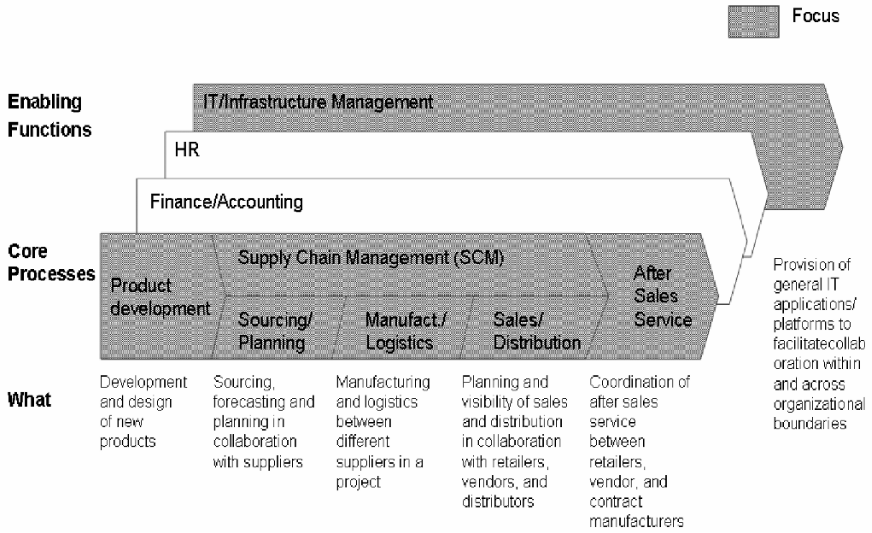

Fig. 2. Supply Chain Management (SCM) processes

Needs

SCM has specific needs in relation to Business Process Management. First of all, there is a need for **benchmarking the processes**. This concept goes further than the internal surveillance of processes; it has to do with the comparison of company performance with the best performance class of the industry from a process point of view, so that a competitive basis exists to improve processes. Consequently, on the one side managers need to know the structure of the processes in order to have a standard basis for there daily control. On the other side, critical points need to be identified in order to be able to measure their progress: Mapping supply chain processes (Supply Chain Mapping) (Christopher 1998):

- Identification of the *activities that add value* and the ones that do not
- How much time is consumed in those activities (time-cost axis)
- Horizontal-vertical times scheme

Once we are able to visualize the structure of our processes, we should try to ensure that we measure those processes in a basis that would let us later compare them with the best performance class of the industry. This is one of the reasons for the existence of reference models that assist the development of the Balance Scorecard: Balanced Scorecard (KPI - Key Performance Indicators) (Christopher 1998):

- Articulate logistics and supply strategy
- What are the measurable outcomes of success?
- What are the processes that impact these processes?
- What are the drivers of performance within these processes?

Why Do Companies Need a Balanced Score Card?

BSC should not be only buzz words applied in some fancy presentations. The true value add of the methodology is performance visibility and this will with the right analyses applied be the key to why we do supply chain management – cost savings. You can only bring cost down, when you know who or what generates costs. Many companies have today recognized this chance and do apply strictly BSC. A second need that we can observe in supply chain management is the **integration**, not only within the organization and supported by the Enterprise Resource Planning systems, but also an upstream and downstream integration. This last idea can be boiled down to the following points:

- Linkage of organizations through information.
- Supply chain integration implies process integration (collaborative working, joint product development, common systems and shared information).
- In the extended enterprise the aim is to create seamless, ”end-to-end” processes so that innovative products are created and delivered to market at higher levels of quality, in shorter time-frames but at a price which in real terms is significantly less than it has ever been in the past (Nokkentved 2000).
- Means:

  - Supply base rationalization
  - Supplier development programmes
  - Early supplier involvement in design
  - Integrated information systems
  - Centralization of inventory

Finally, integration has been reduced to system integration many times. That means that the buyer-seller relationship is only focused on facilitating data but losing the opportunity of planning and developing strategies together. The other way a round, collaboration is needed to seize the opportunity offered by integration processes. **Collaboration is the key**. This is where the two companies completely change the transaction and hence the relationship between each other. True collaboration is defined as (White 2001):

1) Both companies jointly derive the information needed (forecasts, plan, order etc.)
2) Both companies have approval of the information

3) Both companies use the resultant planning information to execute the plan
4) Both companies measure each others performance to the plan
5) Both companies pay themselves based on that performance

There are several cases of where steps 1, 2, and even 3 are achieved but few examples of companies achieving the entire scope. This is a bi-directional model where iterative and flexible business processes are integrated in order to support a mutual strategy.

Collaboration Is the Success Factor for SCM

Collaboration is one of the most critical issues in SCM because the human factor plays an immense role. It is not only about sharing information; it is much more the fact that this collaboration needs to function when something is amiss. The partners need to be able to communicate problems openly and promptly.

This rule does not only apply from one supply chain partner to the other, but within the structures of each of these partners. The challenge in collaboration is to evolve from "keeping things under the hat" to sharing and hence improving glitches. Fortunately good supply chain managers actively apply means and measures to work on collaboration and on trustful communication.

Business Activity Monitoring

In addition to the discussion above, the Business Activity Monitoring (BAM) technology is a major link between BPM and SCEM.

Definition

BAM is the real-time reporting, analyzing and alerting of significant business events, accomplished by gathering data, key performance indicators and business events from multiple applications.

What Benefits Does BAM Provide?

BAM technology, along with real-time enterprise (RTE) strategies, aim to provide instantaneous awareness and appropriate responses to relevant events across an entire enterprise. The BAM benefits are represented in the following figure:

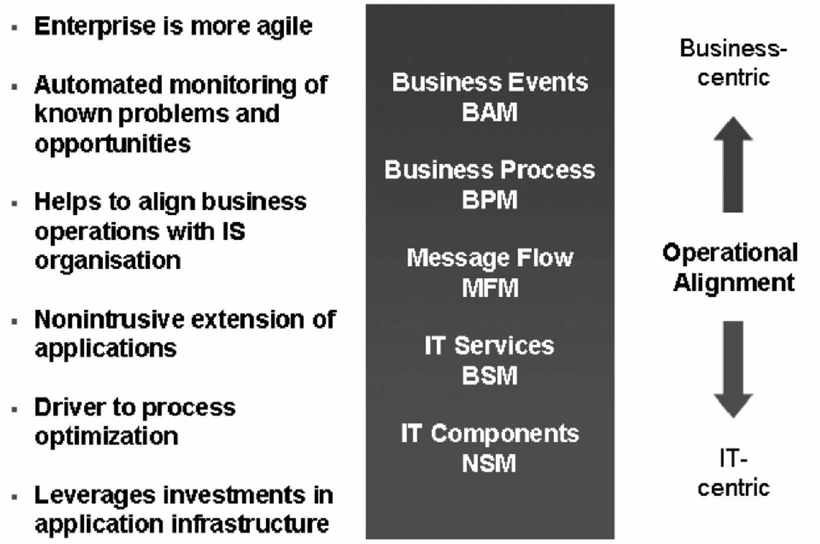

Fig. 3. Benefits of business activity monitoring (BAM)

Changing Old Models

By understanding the power of BAM and some techniques to deploy it, enterprises can benefit from rapid impacts in business process areas where real-time analysis and immediate feedback help change the old models of "management by exception".

The Complexity of BAM Execution

The problem with current systems is in linking information about the events from multiple systems. Most real-time systems are not flexible, and are difficult to adapt to looking at information in new ways, or accepting information from outside its boundaries. In addition, there are few classes of products that supply the ability to run complex rules against an event stream or key performance indicators. A BAM system watches for predefined circumstances to occur, then sends out an alert that the condition has been detected.

BAM Is Not Business Intelligence

Because it's not a real-time application, nor should it be. Executive dashboards are for monitoring key aspects of the "big picture", which, for most enterprises, changes slowly. BAM is targeted at management and operational tasks that fall below the executive level. Those who manage the supply chain, customer relations or sales are more likely to appreciate the rapid and targeted alerts that a BAM system provides. The value of real time is determined by the effect that an alert can have on a business event.

How It Works

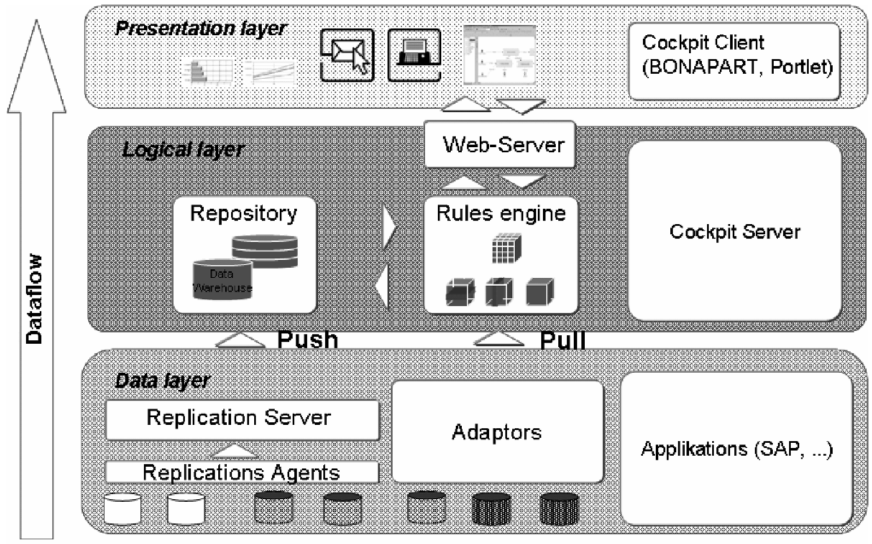

Fig. 4. BAM: how events are processed

The BAM system must first **collect events** and prepare them to be **analyzed by the rules engine**. This is addressed in the event absorption layer. Events can be obtained through active or passive means. *Passive events* are those which are subscribed to, such as from message-oriented middleware. This provides easier access to applications. When integration brokers are used, a BAM system can make use of its routing and transformation services. *Active events* are created by an agent or adapter (see Fig. 4), which may poll applications and databases for changes and threshold crossings.

Other techniques include log file access, screen scraping and the use of ETL tools. The scope of a BAM system depends on the breadth of events that can be absorbed. Once the event has been received, it may be sequenced, validated, filtered for relevancy and saved to an audit file for later analysis.

Events from all sources should be normalized into a common format before processing. During the normalization process, it is useful to add context to the event, for example, looking up the year-to-date revenue of a customer keyed on a customer ID.

More-complicated context will come from BPM systems, where the state of a process within a workflow will be attached to events generated out of that process. Standards such as “Business Process Execution Language” (BPEL) are beginning to play a significant part in putting events into context, which will help BAM systems identify more complicated conditions.

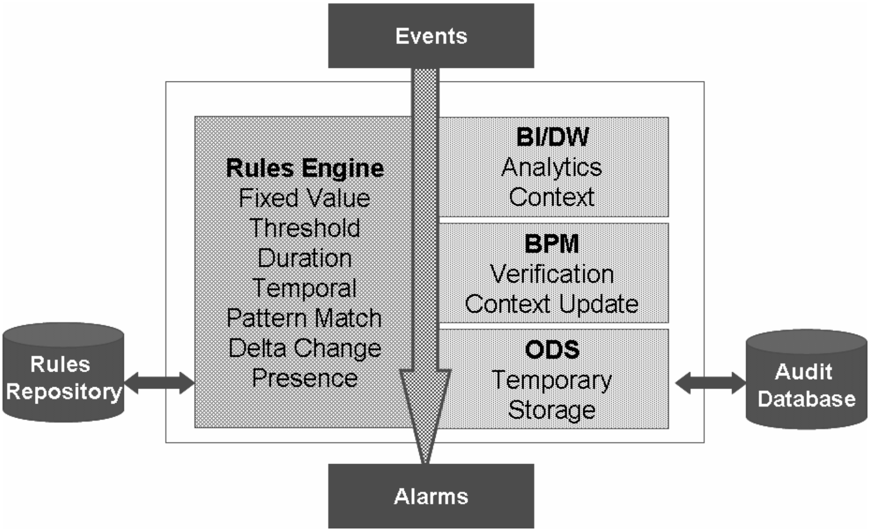

Fig. 5. Main components of a BAM system

The rules engine layer of a BAM system is its most important piece, yet it is the most difficult to implement and to use. Scale and scope are huge issues. Because BAM works in real time, the rules engine must be able to scale performance to the point that it can process an event as it enters the system, sometimes at the rate of thousands per second.

The scope of the rules engine determines the types of BAM applications that can be supported. *Simple rules* look for static values, such as a failure code in a transaction, but more-useful rules require more sophistication. *Duration rules* require a condition to be present for some period of time (see Fig. 5), while *temporal rules* require a condition at a certain time. *Coincidence rules* search for patterns. *Frequency rules* count occurrences. *Delta rules* watch for a rate of change. Rules can be fixed or dynamic.

Dynamic rules may adjust thresholds during the day based on history. Rules may use process engines to orchestrate tasks. For example, an “out of stock” event may trigger an inquiry into the inventory system to verify that the condition still exists. Predictive analysis uses BI technology to find correlations in a data set of events or pattern matches event streams to previous occurrences of problems and opportunities. The BAM system should include utilities to test the rules with dummy events, and an audit facility to allow subsequent analysis of its accuracy. Links with data warehouse and BPM systems may be integrated within the product or use existing enterprise resources. Background processing may be used to improve rules based on an analysis of events and on which rules have fired.

BAM & Supply Chain Event Management

On the following paragraphs we will go through the concept of Supply Chain Event Management (SCEM) and how it is implemented. The table below collects the SCEM definitions (Alvarenga a. Schoenthaler 2003):

Supply Chain Event	Any individual outcome (or nonoutcome) of a supply chain cycle, (sub) process, activity, or task
Supply Chain Event Management	The application of statistical, process, and technology identification and control solutions to standard and nonstandard suplly chain events
Event Category	A logical grouping of supply chain events
Event Probability Index(EPI)	The statistcal measure, on a scale of 0 to 1, of the tendency of an event to occur within the supply chain (1 = always occurs, and 0 = never occurs) over a given interval
Standard Event	An events that tends to occur within the supply chain; that is, has an EPI of .50x or higher
Non-standard Event	An events that tends not to occur within the supply chain; that is, has an EPI of .49x or lower
Event Management Plan (EMP)	A document process that outlines the steps taken to control or react to an event
Planned Event	An event for which a documented EMP exists
Unplanned Event	An event for which a documented EMP does not exist

Fig. 6. Supply Chain Event Management (SCEM) definitions

The SCEM goal is to improve overall supply chain effectiveness and reduce supply chain costs by managing events. Any suggested approach to SCEM needs to meet the following criteria:

- Must take into account all levels of supply chain events: cycle, process, activity, and task.

- Should be capable of driving benefits without any associated SCEM technology, which is still in its early stages of development.
- Must complement existing improvement methodologies such as total quality management and Six Sigma.
- Must be applicable to all areas of supply chain management: design, plan, source, make, sell, deliver, and maintain.
- Must be easy to understand and easy to measure in multiple languages or cultural environments.
- Must be based on statistical evidence that supports event management decisions.

The implementation of the supply chain event management approach follows a sequence that would be familiar to anyone who has undertaken process improvement activities such as Six Sigma or business process reengineering:

Phase 1: Baseline

- Map events to the existing Business Process Model.
- Define metrics.
- Establish performance.

Phase 2: Strategy

- Set event performance targets.
- Establish potential value of event shifts.
- Define shift plans.

Phase 3: Shift

- Implement event management plans.
- Implement associated technology.

Phase 4: Measurement

- Re-establish event performance.
- Analyze against goals.

A major part of the implementation phase is to create a “cockpit” to monitor event management progress. During implementation, it is important to keep in mind that event data will generally come from three sources:

1) Web enabled sources, such as the World Wide Web, corporate extranets and intranets, partner extranets, and competitor extranets;

2) Corporate applications, which include enterprise resource planning (ERP), APS, customer relationship management (CRM), supplier relationship management (SRM), and manufacturing execution systems (MES); and
3) Proprietary systems, mainly legacy systems developed solely within one business entity and those inherited as a result of merger and acquisition activity.

Cockpits that aggregate these data sources in support of an event performance grid can be custom developed or they can be implemented using commercial software.

The Value-add of SCEM – Less Might Be More

Throughout this article we inquired about value-add. The value-add of SCEM can be incredible, if correctly applied.

More often than not, when choosing events for monitoring, there is a whole array of events available, and often all will be applied. However, as commonly known too much information can and will confuse.

The application of SCEM should always be based on exception management. Customers in general do not want the overkill of information but only the critical events and foremost not only this but also an emergency execution plan.

Here all common SCEM tools do reach their limits, and again intelligent SCEM tools need to be combined with the human factor. The operator needs to analyse the event and based on pre-defined parameters an emergency recovery can be executed.

Supply Chain Operations Reference-Model (SCOR)

The existence of an SCM business process model being a prerequisite for SCEM creates the question of how to get one. Reference models can be an answer to that question.

The Supply Chain Operations Reference-model (SCOR) is an example for such a model. The Supply Chain Operations Reference-model (SCOR) (see Fig. 7 and Fig. 8) has been developed and endorsed by the Supply Chain-Council (SCC), an independent not-for-profit corporation, as the cross-industry standard for supply-chain management.

It is focused on performance improvement and it classifies the collaborative processes. European companies like Siemens, Nokia, Statoil, Grundfos, BASF, Lego, and Electrolux are using the SCOR-model for their business developments.

SCOR Spans:

- All customer interactions, from order entry through paid invoice

- All product (physical material and service) transactions, from your supplier's supplier to your customer's customer, including equipment, supplies, spare parts, bulk product, software, etc.
- All market interactions, from the understanding of aggregate demand to the fulfilment of each order

SCOR Does Not Attempt to Describe Every Business Process or Activity, Including:

- Sales and marketing (demand generation)
- Research and technology development
- Product development
- Some elements of post-delivery customer support

SCOR Assumes But Does Not Explicitly Address:

- Training
- Quality
- Information Technology (IT)
- Administration (non-SCM)

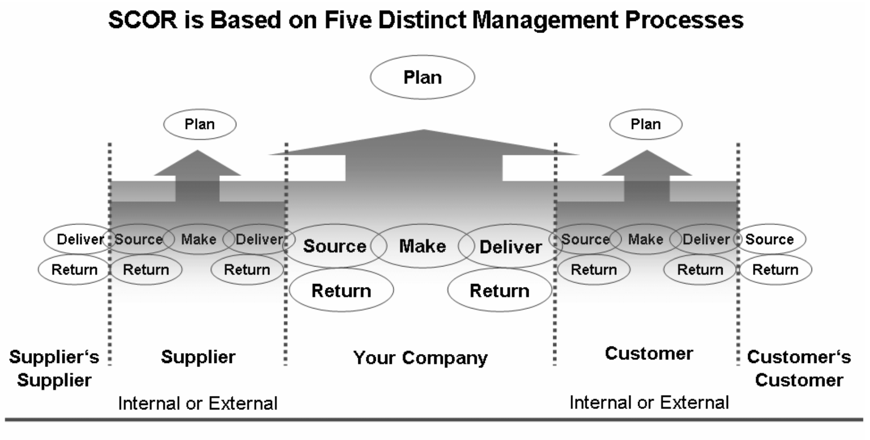

Fig. 7. SCOR is based on five distinct management processes

Scope of SCOR Processes:

Plan: Demand/Supply Planning and Management

- Balance resources with requirements and establish/communicate plans for the whole supply chain, including Return, and the execution processes of Source, Make, and Deliver.
- Management of business rules, supply chain performance, data collection, inventory, capital assets, transportation, planning configuration, and regulatory requirements and compliance.
- Align the supply chain unit plan with the financial plan.

Source: Sourcing Stocked, Make-to-Order, and Engineer-to-Order Product

- Schedule deliveries; receive, verify, and transfer product; and authorize supplier payments.
- Identify and select supply sources when not predetermined, as for engineer-to-order product.
- Manage business rules, assess supplier performance, and maintain data.
- Manage inventory, capital assets, incoming product, supplier network, import/export requirements, and supplier agreements.

Make: Make-to-Stock, Make-to-Order, and Engineer-to-Order Production Execution

- Schedule production activities, issue product, produce and test, package, stage product, and release product to deliver.
- Finalize engineering for engineer-to-order product.
- Manage rules, performance, data, in-process products (WIP), equipment and facilities, transportation, production network, and regulatory compliance for production.

Deliver: Order, Warehouse, Transportation, and Installation Management for Stocked, Make-to-Order, and Engineer-to-Order Product

- All order management steps from processing customer inquiries and quotes to routing shipments and selecting carriers.
- Warehouse management from receiving and picking product to load and ship product.
- Receive and verify product at customer site and install, if necessary.
- Invoicing customer.
- Manage Deliver business rules, performance, information, finished product inventories, capital assets, transportation, product life cycle, and import/export requirements.

Return: Return of Raw Materials (to Supplier) and Receipt of Returns of Finished Goods (from Customer), including Defective Products, MRO Products, and Excess Products

- All return defective product steps from authorizing return; scheduling product return; receiving.
- Verifying and disposition of defective product; and return replacement or credit.
- Return MRO product steps from authorizing and scheduling return, determining product condition, transferring product, verifying product condition, disposition, and request return authorization.
- Return excess product steps including identifying excess inventory, scheduling shipment, receiving returns, approving request authorization, receiving excess product return in Source, verifying excess, and recover and disposition of excess product.
- Manage Return business rules, performance, data collection, return inventory, capital assets, transportation, network configuration, and regulatory requirements and compliance.

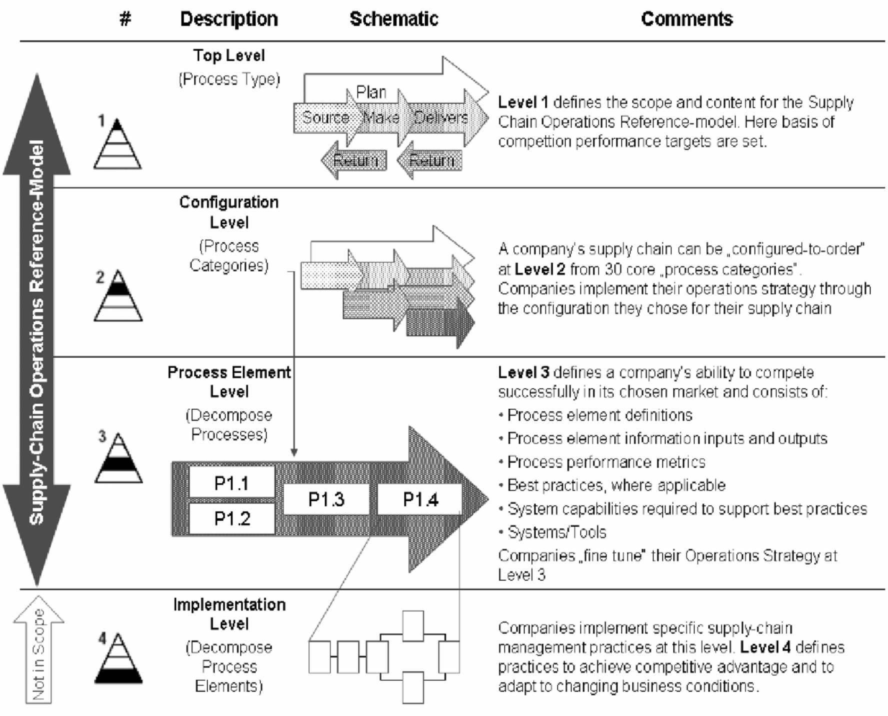

Fig. 8. SCOR spans 4 levels

Toolset for BPM – BAM - SCEM

Of course, the described objectives can not be fulfilled without an appropriate set of tools. As an example, the use of the BONAPART® product family will be shown here (see Fig. 9 and Fig. 10). The BPM component is BONAPART®. BONAPART® is used to structure, analyse, simulate and monitor business processes. BONAPART® delivers a process-oriented view of the organization and integrates information from the following different types of business objects:

- Tasks
- People
- Resources
- Information containers
- Information
- Info transfer devices
- Job titles
- Business entities
- Managers

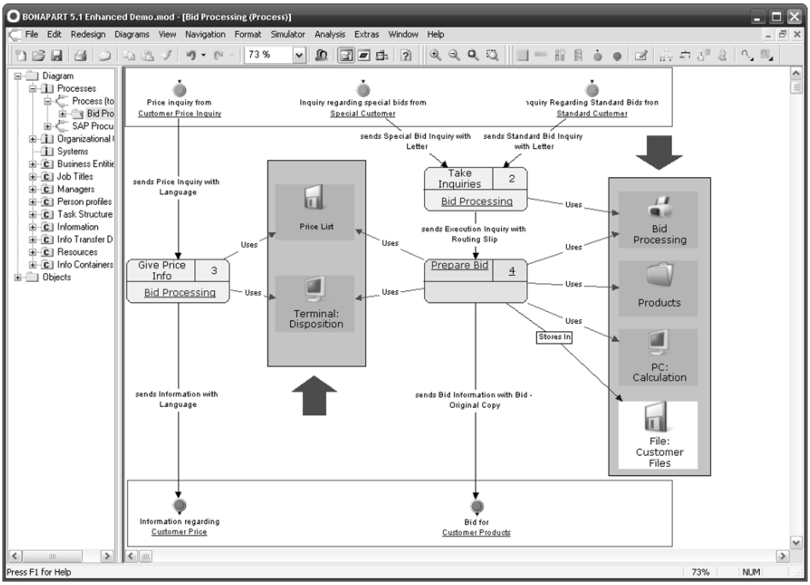

Fig. 9. SCOR-compliant reference model in BONAPART®

An existing SCOR-compliant reference model offers an easy entrance to BPM for SCEM. BONAPART® Cockpit is a BAM tool which allows representation of event-driven key indicators obtained from real-time applications within graphical process models. BONAPART® cockpit identifies in real time the duration of an activity. Moreover, the Cockpits rules engine is able to capture data to build up more complex KPIs, like lead times or rotations. The user specifies the maximum and minimum value it should have to enable the traffic light alerts.

Actual data will be compared with “to be” figures so that the data can be graphically visualized in BONAPART® models. In addition, those responsible for processes can be informed via WAP, Email and SMS. Using this early warning system monitored process data become transparent and detailed information can be delivered to better comprehend short-term or mid-term measures. Additional reports can be created for productivity, efficiency or process costs.

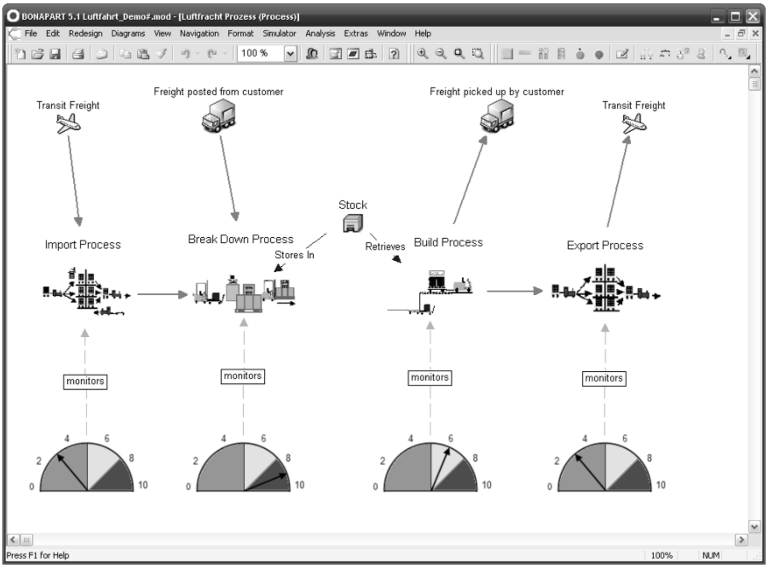

Fig. 10. BONAPART® Cockpit - active process monitoring

The combination of both tools offers essential functionality for BPM and SCEM in the areas of process design, analysis, simulation, publishing and monitoring. Of course, there are other, more specific areas in the SCEM market, where specialized solutions can be found. Two problems come together with these software systems:

- Since SCEM technology is still in its early stages of development, specialised solutions typically suffer from a lack of maturity.
- Since they are specialized, they are not able to fulfil the wide-spread requirements which come along with BPM and SCEM (Summary):
  - Process modelling functionality
  - Simulation functionality
  - Existence of a reference model
  - Ability to benchmark processes

- Ability for integration in existing organizational and IT-Landscape
- Ability for collaboration
- Ability for real-time monitoring
- Ability to collect events from existing infrastructure
- Existence of a rules engine layer

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Supply Chain Event Management: Innovation in Logistics Services

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Introduction

Innovative logistics management is one of today's critical competitive factors. The general conditions of logistics are increasingly changing. Product capacities which also concentrate incrementally in Asia face markets which consume "on-demand". Meeting these demands is the primary goal of Supply Chain Management. The system-based and holistic development of logistics solutions is an essential factor of success in the "on-demand"-oriented supply to customers. The supply chain dilemma is on one hand, the increasing complexity and on the other the necessity to drastically improve information and transparency. Especially the optimisation of capital lockup by reducing inventory requires a rigorous improvement in terms of actual data availability.

Focus Solely on Costs and Speed Fails

In reality, supply chain management is rarely implemented consistently. Particularly logistics service providers often learn that an efficient and innovative solution is blocked by purely transactional- and cost-focused tenders. Meanwhile, structural data regarding actual quantities and processes are described in detail in common tender processes. Most preset answering structures only allow one goal: to reduce costs for transactions. Logistics chains purely optimised by costs and speed are eventually too slow if market changes press for adjustments. The changes in market environment do not require static relations but dynamic "supply" networks. The more focus is on costs, the more logistics participants are involved who represent their individual interest. Integrated innovative solutions cannot be reached in this way!

The Triple ”A“ Supply Chain

Adaptability, flexibility and collaboration are the key messages which stand for the new generation of SCM. Only the ability to operate efficiently and to structurally change the logistics chain as quickly as possible if needed assures competitiveness (Agility). This requires embedding in dynamic logistics networks (Adoption) and reshape processes with new partners – also by overcoming of some individual interests (Alignment). Deriving from this conclusion, arvato services started the approach to strategically invest in an improved technology platform and to further develop the previous partner and vendor models. It was aimed to form the foundation for a new Supply Chain which creates transparency by flexibility and reliability, and which offers new service dimensions. For reaching these goals, the Supply Chain Event Management is of central significance. It is used as method and tool to integrate processes, inventory and partner in a comprehensive and transparent way, and to manage pro-actively.

Logistics Success by Pro-active Management of Processes and Costs

Supply Chain Event Management provides control and the pro-active management of processes. Enterprises manage their processes based on comprehensive planning, amongst other things. However, with growing planning reliability and more complex processes, the sensitivity of planning increases by occurrence of unexpected event. Especially in the era of “on-demand” and “just-in-time”, manufacturer have no possibility anymore to react to unscheduled events, e.g. great demand, and to fulfil additional orders. As consequence, the forecast is stepped up and production capacities extended. The dreaded “bullwhip effect” occurs which is boosted by additional complexity of multiple products and several customers.

SCEM Software enables enterprises to react quickly and to some extent automatically to unexpected events – without re-working the planning’s completely. SCEM applications achieve this by pro-active messages to the important process participants on the occurance of certain events respectively on the non-occurance, e.g. going below minimum inventory, delayed deliveries, etc. Upon the occurance of these events, a corresponding action can often be executed, e.g. sending of an SMS or an Email. By transparency of unscheduled events, problems in the Supply Chain can be analysed more quickly and solved.

The transparency is the greatest benefit/advantage of SCEM. Only visible problems can be solved. However, problems are often detected too late and have to be solved in a laborious and expensive way. Reactive behaviour ensures neither the service level nor customer satisfaction.

The transparency gained by SCEM primarily offers a continuous fine-tuning of processes and planning’s. Thus, unscheduled events and exceptions turn into chances to optimise planning’s, to avoid delayed deliveries, and to reduce costs. In the long term, SCEM Software does not only improve efficiency but also increases customer satisfaction.

SCEM Software can react automatically to events, e.g. produce an electronic order when reaching the defined minimum stock level. This is realised by the integration of SCEM Software with different corporate system such as ERP systems. Furthermore, SCEM also offers the basis to analyse the reason for unscheduled events and to develop solutions. SCEM's entire added value emerges when the basic system architecture collects data from several sources of information from within and outside the enterprise and so transparency across enterprises are made visible in the supply chain. The exception messages produced by the SCEM system should be directly sent to the process participant who is best in solving the specific problem, independently of his/her position and his/her internal or external corporate seniority. SCEM systems become even more effective when linked with knowledge data bases which provide the informed process participant with a proposed solution.

Supply Chain Event Management Is Interdisciplinary

However, the risk using SCEM is basically to use it as an isolated reactive tracking system instead of a pro-active and cross-system control of the supply chain. One example: The Event Management System informs dispatch manager on a late inbound delivery. We further assume the Transport Management System is directly linked to the Warehouse Management System (WMS) and to the Order Booking System but none of the systems transfers the data to a superior analysis system. The WMS would inform the dispatch manager who would change the next delivery for the relevant customer. At the same time, a customer service representative would inform the customer on the reduced delivery, based on the data from the order booking system. In the meantime, the dispatch manager, who had received the original message, could have found the required stock elsewhere in order to level out the delayed inbound delivery. The customer can now receive his delivery on time, but none of the other employees who react to the respective messages could have known this at the beginning. This unavailing effort could have been avoided if the organisation used a comprehensive analysis system with alert functionality. In addition to the message on the delayed inbound delivery, every party involved would have also received data on stock level, allocation and open orders in an aggregated view. The first and only decision made would have been the stock transfer to fulfil the order. Information to the customer on the delayed delivery would have not been necessary. Prerequisite for the successful application of SCEM is also the conjunction with internal and external systems to receive constant real time data of the entire supply chain. The supply chain of today is characterised by the fact that numerous external partners with different system standards (e.g. de-centralised warehouses and depots as well as differently specialised transport service providers are involved. The setup of a mutual platform which creates an integrated data acquisition along the supply chain can be looked at as considerable challenge because it requires much more than only technology development. Rather, it involves the commitment to create new structures with the partners.

Especially in this aspect, it has shown that not all previous partners have been capable and/or willing to provide this transparency by data interfaces. If the selection and integration of partners have been successful, the SCEM however, offers a noticeable value add in terms of monitoring and pro-active control of the supply chain. This can be made clearin an additional example regarding spare parts logistics: An urgently needed spare part for a machine has to be delivered within 4 hours. Since the central warehouse is outside the 4-hour radius, the delivery is carried out by a local depot (see Fig. 1).

- Event 1: The delivery order arrives at the central spare parts warehouse. A SMS is automatically created by the SCEM system at order receipt. It notifies the procurement manager of the warehouse identified/determined by the system of/about the order. At the same time, the delivery note is printed in the depot.
- Event 2: The procurement manager at the depot has to confirm the receipt of the delivery note within 30 minutes via a web application. If he/she exceeds the 30-minute period, the employee at the main office receives a SM or an Email, and calls the procurement manager at the depot.
- Event 3: The spare part is commissioned at the depot.
- Event 4: The order is ready for collection by the driver at the goods issuing department within 60 minutes after order receipt. Now the technician receives a SMS by the SCEM system confirming that the spare part is en-route.
- Event 5: The good is delivered within 4 hours after the order receipt. If the delivery is not confirmed after 4 hours, the service representative will be notified via Email and SMS.

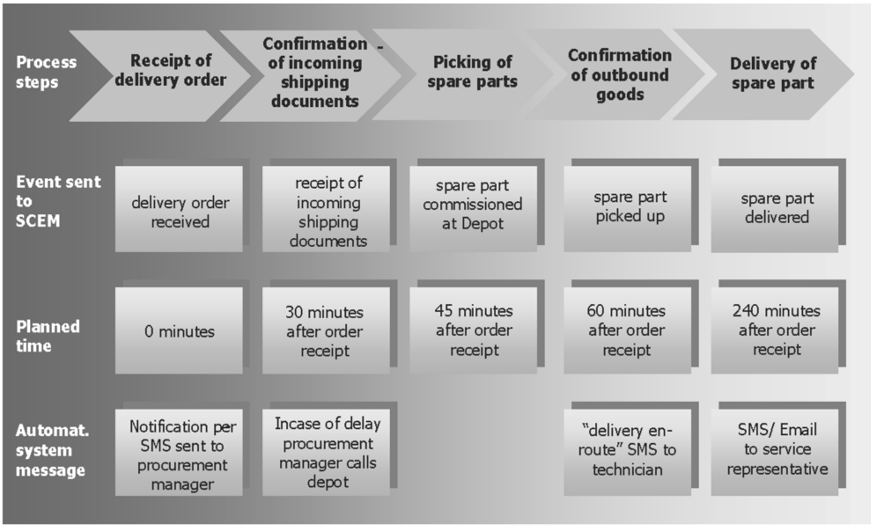

Fig. 1. Process steps of an express delivery controlled by a SCEM system

By the prompt control and the use of automatically generated messages, the number of potential problems is reduced and the employees have the opportunity to promptly initiate counter or alternative measures (e.g. delivery out of a different depot in case of unavailability at the first depot). Furthermore, the collected data support the analysis and optimisation of existing processes internally as well as externally at service and transport service providers. The performance is transparent at any time and can be used as basis for performance-related pay. Based upon the link of SCEM with the financial system as described above, it is even possible that only on-time deliveries are to be paid via credit memo procedure to the transport service provider. Only the confirmed event “good delivered on time” by the transport service provider produces the credit memo procedure in the financial system. Undelivered goods or goods delivered too late are not paid or paid with discount.

Thereby, the motivation of external partners to improve their processes with regards to customer satisfaction is increased.

Realisation of SCEM Systems

SCEM systems cannot be looked at as self-contained applications but rather as a system architecture which are arranged according to the individual supply chain processes of an enterprise. Comprehensive IT and logistics know-how is essential prerequisite.

As mentioned before, a SCEM solution reveals its full benefit through the integration of different system across enterprises. Internally, this could be WMS; ERP and CRM systems. Externally, transport service providers, depots and technicians have to be linked. The multiplicity of different IT standards makes the linkage of all desired system extremely complex so that a gradually link-up of individual systems is recommended.

The various track & trace systems of transport service providers supply different codes for the same result, for example. The SCEM system has to be capable of translating hundreds of different code messages of transport service providers into its defined events (e.g. goods delivery). Upon successful implementation of the SCEM system, the completeness and quality of data are often the major difficulty. Accordingly, the implementation of SCEM requires not only changes in your processes but also changes in processes of your service partners.

Conclusion and Forecast

SCEM offers possibilities especially in the field of spare part logistics for improving operative delivery reliability, and for a well-founded analysis and optimisation of processes. However, prerequisite is the use of SCEM as a comprehensive platform which aggregates information from internal and external data in a reasonable form, and which automatically forwards messages to the defined process participants in case of unscheduled events. The system linkage of different internal and external systems is one of the major challenges. If this is managed successfully, the utmost attention is to be dedicated to the quality and the completeness of the collected data.

Numerous new aspects of SCEM are currently being planned and implemented. Thus, not only processes and their progress are increasingly monitored but also different events such as a vigorous movement of transport containers and if necessary, sent as an event to the SCEM system via data transfer. Also the opening of transport units such as containers can be defined as an event depending on a preset time e.g. customs inspection, or can be defined and registered as theft outside the preset time.

Therefore, the possible field of application of SCEM is not utilised to its full potential. It is reckoned that SCEM systems and interfaces will increasingly become a central part of innovative logistics solutions.

As one of the first users worldwide, arvato services introduced the Supply Chain Event Management based on SAP some years ago, and have controlled distribution and spare part logistics processes for leading high-tech companies. The arvato SCEM system offers track & trace across carriers for fourteen linked transport service providers, an automated freight charges billing system as well as a web-based monitoring and reporting. Almost 3 million deliveries p.a. are reliably controlled by the system.

arvato services, a subsidiary of arvato AG, is a leading service provider for effective solutions for customer communication and Supply Chain Management in Europe and overseas markets. arvato services offers its customers one-stop-shopping concepts in the fields of CRM / SCM consulting, customer loyalty, data management, letters hop, customer service, logistics and finance, supported by IT solutions. Worldwide more than 27,000 arvato services' employees care for your customers' clients.

SCEM-System to Support the Development of Consumer Promotion

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Introduction

In 2002, Deutsche Woolworth GmbH & Co. OHG began to launch weekly consumer promotions with varying subjects in the context of a reorganisation process. These promotions comprise about 60 to 120 products respectively, most of which are procured in the Far East. In order to guarantee an on-time delivery to the individual stores, a Supply Chain Event Management System based on internationally standardised codes and message types was introduced.

Deutsche Woolworth GmbH & Co. OHG (DWW) was founded in 1926 as a subsidiary of F.W. Woolworth Company. In 1998, DWW parted with its American parent company within the framework of a management buy-out. Today, the company has about 340 stores in Germany and Austria with a total turnover of approximately € 900 million (2005). DWW is known as an „adventure discounter" with a broad product range, consisting of non-food and drugstore products (approx. 51%) and textile products (49%).

When Deutsche Woolworth first introduced consumer promotions in 2002, very quickly it became clear that the methods of order processing used until then were no longer adequate. Despite the fact that the promotion products only make up for less than 10% of the entire product range, they account for about 20% of the total turnover.

Furthermore, as a discount market, the company did not want to have these products delivered a long time before the start of the actual promotion campaign, in order to avoid unnecessary capital lockup. Thus, the Supply Chain Management decided to introduce a just-in-time concept, which, at the time, was already widely used in the automotive industry, but was a rather new thing in commerce. In accordance with this concept, the goods were to be delivered as late as possible on the one hand, but still early enough to guarantee an on-time delivery to the stores without additional costs on the other hand. Starting with the promotion date, average transport times were determined that defined exactly when the goods had to be where in order to comply with the requirements of the plan.

In order to enable employees to check whether the set deadlines were met, a Tracking & Tracing system was established as a first step of information. Talks with the transport service providers revealed that although they all used a Tracking & Tracing system, some problems still existed:

- The systems all had different user interfaces
- All systems only made allowance for the interests of the transport service provide
- All systems used different codes

In order to avoid having to train the respective employees to use a variety of different systems and in order not to depend too much on the transport service providers, DWW decided to create their own Supply Chain Event Management-(SCEM) System

- based on standard message types
- using standardised codes for the documents, the locations and the statuses of the deliveries.
- The results of which are displayed in the order processing system of DWW.

The difference between the Tracking & Tracing systems used by the transport service providers and the SCEM system is that it automatically and timely informs the user about any deviations from the specified values. In order to meet these requirements, DWW launched a project in cooperation with GS1 Germany and Birkart Globistics. The integration of GS1 Germany guaranteed that the solution would be internationally valid and recognised. With Birkart Globistics being involved in all areas of the supply chain of Deutsche Woolworth Ltd., a comprehensive solution could be found which not only covers the individual segments but the entire chain from the supplier in the Far East all the way to the stores. The project partners decided at a very early stage that EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport, www.unece.org/trade/untdid/directories.htm) was the standard to be used. In comparison with XML (Extensible Markup Language), EDIFACT offers the following advantages:

- It is internationally standardised,
- It is a standard that is widely used in Europe,
- The data volume to be transmitted is significantly lower.

Incoming Transports

The starting point for consideration was the description of the processes for the individual procurement channels (see Fig. 1: Milestone for imports from Far East). In a second step, these descriptions were then converted into the desired reporting points.

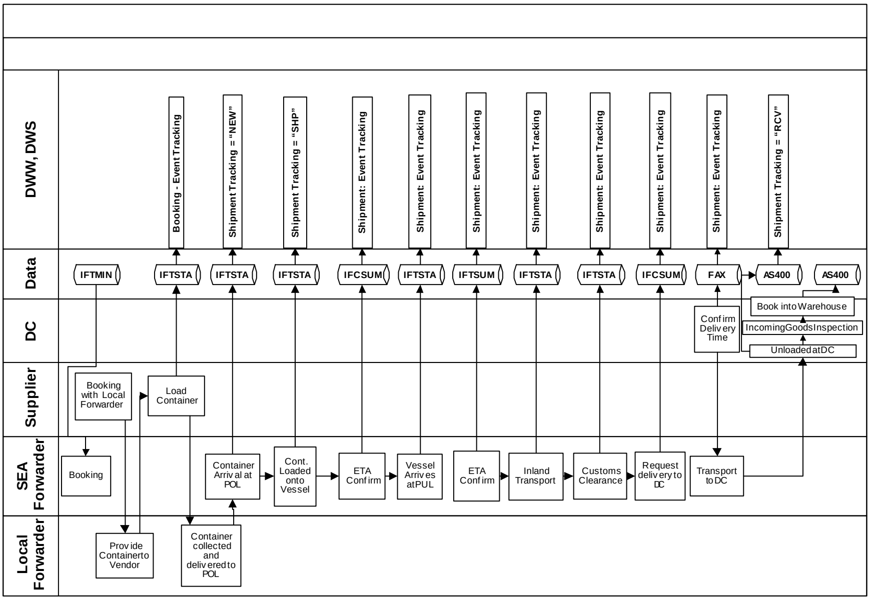

Fig. 1. Milestone for imports from Far East

Above all, the interfaces between different companies were defined as reporting points, e.g. the interfaces between DWW and the supplier, between the supplier and haulage contractor, or those between the haulage contractor and the ship-owner, etc. According to experience, a large part of all (communication) problems are created at these interfaces. Therefore, message pairs were defined at all these points: one message reporting the delivery of goods to the next process partner and another message to confirm receipt of said delivery. This guarantees that the partner currently responsible can be seen on the DWW system at all times. These messages must determine:

- The location where the goods are at any given time,
- The relevant documents and
- Their status.

Three code types were defined for identifying locations:

1) the International Location Number (ILN)
2) the code from the UN/LOCODE list (United Nations)
3) the code from the NCTS (New Computerized Transit System) tax proceedings

DWW has allocated an ILN to all its stores as well as for all loading platforms of all distribution centres. Thus, all incoming deliveries as well as deliveries to the stores can be precisely routed. Yet, there are no ILNs available for international dealings. In these cases, the partners resort to the UN/LOCODE list. This list contains codes for various locations worldwide (e.g.: DEBNN = Bönen)

In addition, the codes from the NCTS proceedings are also permitted, especially for the cross-national inland transports. Thus, the reporting point entitled “customs clearance“ can be marked clearly. In the case of problems with customs clearance and in order to be able to specify, which documents might be missing, reference is made here to the United Nations 1001 List. This list contains all documents commonly used in international merchandise traffic as well as their codes. This guarantees an unambiguous communication even across country and language barriers. The valid statuses for all reporting points were chosen from the list of Trade and Transport Status Codes. Special attention was given to the fact that there must be at least one positive and one negative status code respectively for each reporting point.

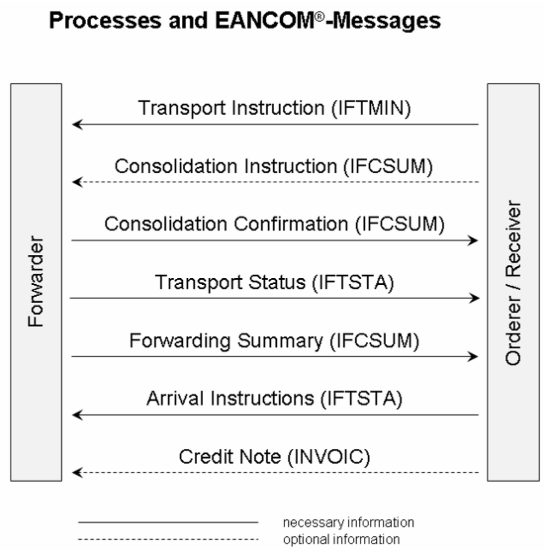

Fig. 2. Messages for inbound transport

Thus, by definition, a missing message will be reported as negative, („No news are bad news“), which, in turn, will lead to an alert for the responsible administrator. The message types to be used were defined as follows (see Messages for inbound transport):

- Shipping order (IFTMIN = Instruction Message)
- This is used in order to convey information about the goods to be shipped to the transport service provider.
- Combined shipment message (IFCSUM = Forwarding and transport shipment charge calculation message)
- This message gives the transport service provider the order for consolidation, i.e. which orders must or may be loaded into one container. This guarantees that only those goods with the same delivery date and destination are loaded into the same container.
- At the same time, the service provider uses this message to confirm the consolidation and to advise the arrival of the delivery.
- Status report message (IFTSTA = International multimodal status report message)
- The status report message informs DWW about the location and the status of the deliveries. On the other hand, it is used to inform the service provider about the delivery date and destination.
- In order to guarantee that the information received is always up to date, it was agreed that at least one status report message shall be sent per day and order. Should there be any delays in shipment, this message shall always convey the estimated time of arrival at the destination port (ETA = Estimated Time of Arrival).
- Invoice (INVOIC = Invoice message)
- The invoice is used inversely in order to announce to the service provider the expected credit note.

Distribution

The same message types are also used for distribution (see Fig. 3: Messages for outbound transport). Yet, as most cases here are actually one-time transactions which have to be closed by the following working day, a lot less reporting points are needed. Furthermore, there is no combined shipment message, any loading equipment is registered and monitored as a separate delivery.

As with the incoming transports, the haulage contractor receives a shipment order (IFTMIN). For this, every shipping unit (e.g. one pallet) is furnished with a bar code in accordance with the EAN128 standard, the number of the shipping unit (NVE). As an order is shipped with the loading of every single shipment unit, the merchandise planning department can estimate the volume to be shipped and to make arrangements for the capacities needed at a very early stage already.

For every transaction, the individual loading equipments are scanned and a status report message is sent (IFTSTA). Thus, completeness can be monitored and checked at every single transaction point. Furthermore, the store manager always knows what volumes to expect on the next day. This enables him to plan his staff capacities for the reception and the storage of the goods on the previous day already.

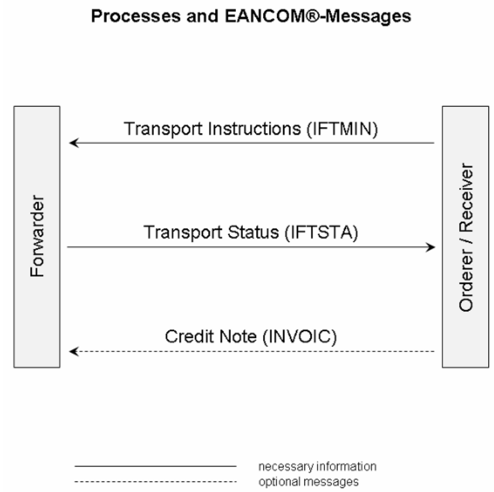

Fig. 3. Messages for outbound transport

Upon reception of the shipping units at the individual stores, the NVEs are scanned again, thus closing the delivery process. A comparison between the targeted delivery date/time and the actual scanning date, the punctuality of delivery of the respective transport service provider is determined.

Fast Tracks

What if there is a transport delay after all? For these cases, so-called fast tracks were established, to make up for delays. However, this is only possible because Woolworth has adjusted its entire supply chain in accordance with the principle "Punctuality over Speed". The costs for using a fast track must always be borne by the party responsible.

- **Faster ship:** As a rule, Woolworth does not use the fastest ship for the transport from the Far East to Europe. In the beginning, this was due to cost reasons, but later developed into the most important element of flexibility of the supply chain. It became clear that the capital costs which had increased due to the longer transit time were overcompensated by lower transport costs. Surely, this result is valid especially for discounters such as Woolworth but not necessarily for other companies. Even if there are delays in production and if the deadline for loading at the port is missed, an air freight delivery is usually not necessary. In most cases, a faster ship with less stops will suffice to make up for the delay. The advantage for the transport service provider is that they must not at all costs use the next ship available but that they can choose (within a limited scope) the shipping company that offers the best deal. This, in turn, is beneficial to Woolworth inasmuch as it entails lower shipment costs.

- **Truck delivery:** As a rule, the delivery from the European arrival port to the Deutsche Woolworth distribution centres is carried out via inland navigation vessels from Rotterdam or via rail from Hamburg. In the case of a delayed arrival of the ship from the Far East, there is the possibility of using a truck instead of an inland navigation vessel or railway, in order to make up for time lost.
- **Prioritisation of processing:** On average, the distribution centre needs about 3 days to process the goods. By shifting priorities of processing and changing the staff's work plans, this time can be reduced by up to 2 days.
- **Distribution with KEP service providers:** If none of the above mentioned measures suffice to make up for the delay, the last resort is the distribution of products via a parcel delivery service. As the costs for this are about ten times as high as the choice of a faster ship or a delivery by truck, all other possibilities must always be exploited first, before this last alternative may be used.
- **Air freight:** In most cases, the delay in production only adds up to a few days. In these cases, the measures described suffice to make up for the delays. However, in the case of a longer delay, the goods must be shipped by air. As this is a very expensive alternative, it is only used very rarely.
- **Promotion:** A last alternative, which is often overlooked, is to take the item concerned off the promotion list. Usually, there will always be more articles photographed than actually used. Thus, the delayed goods can either be stored at the distribution centre for a later promotion campaign or, in the case of fashion textiles, distributed to the stores, where the sale may be supported with individual, local measures if necessary.

Result

The result proves Deutsche Woolworth right. In 2005 and 2006, the average punctuality of delivery was 99.2%. During this period, service providers were changed various times because either the costs did not match the standard of an "adventure discounter" or because the delivery service required could not be maintained at a constant level. In all these cases, the choice of an own SCEM system based on internationally standardised messages proved of value, because there were no changes whatsoever for the employees working with this system on a daily basis. This result persuaded the jury, to award the Deutsche Woolworth the Logistics Service Award and the European Supply Chain Excellence Award in 2006.

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Dynamic Models for Simulation and Optimization of Supply Networks

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Introduction

We are interested in supply chain event management (SCEM) which is a part of supply chain management. In our considerations a supply chain consists of suppliers, manufacturers, warehouses and stores. Goods or parts can be produced and distributed among different production facilities and stores. Further, different suppliers provide possibly different raw materials or parts in a preliminary stage of production. We call all arising machines, stores, etc. and their interconnections the supply network. Based on description, we understand as SCEM the cost efficient distribution of parts among different locations and at different times in a supply chain. Additionally, SCEM monitors and measures current business processes and predicts future work loads of machines, buffer level of stores and other application dependent events.

In this article we present a model for a supply network and results on the SCEM based upon the introduced model. Here, we give a description of each single part of the supply network by continuous equations. The equations are derived from only a few common major assumptions. The model can be extended to include further phenomena and we give some examples of such extensions below. The continuous models have gained attention recently, in particular, in the case when the number goods or parts in the network is of large scale. Further, in view of the SCEM, the models can be easily used to obtain the optimal part distribution or to predict further states of the supply network.

In the literature, supply chain modeling is characterized by many different scales and several different mathematical approaches. Two common approaches are as follows: On the one hand there are discrete event simulations (DES) based on considerations of individual goods or parts. On the other hand, continuous models using differential equations have been introduced and investigated during the last years, see (Armbruster et al., 2004/2006; Daganzo, 2003; Degond et al., 2007; Göttlich et al., 2005/2006) and (Baumol, 1970; Forrester, 1964). These models describe the evolution of flows, in particular the flow of goods, in a single supply chain of a network. Under suitable assumptions some of the continuous models are equivalent to DES. However, the continuous models have the following advantages: non–linearities can be easily included in the dynamics and there the models are scale–invariant in the number of parts.

In many applications the simulation and prediction of supply chain behavior over time is only one important aspect. Another question arising in operations research is the optimization of supply chains. This problem often refers to a variety of problems, where a couple of independent entities (such as companies or machines) depend on each other in a graph–structure. The output of each entity is fed into the next entity with or without buffering and with or without delay in time. Typically, models based on mixed-integer programming (MIP) are used, see (Bixby et al., 2004; Fügenschuh et al., 2007; Voß a. Woodruff, 2003; Wolfsey a. Pochet, 2006) , to describe this phenomena and to find the optimal load balance on the interconnections between different entities. We present a framework on how to deal with such a question having the continuous model as description of the supply network. We show that after suitable modifications the presented model also allows for a representation as MIP. The results of the optimization of the MIP is understood as SCEM.

Summarizing, we present a way of modeling supply chains incorporating simulation and optimization issues. The models are implemented and solved using standard commercial solvers and in particular, CPLEX v10.0 (ILOG CPLEX, www.cplex.com) and MATLAB (MATLAB, www.mathworks.com).

Simulation Models

Discrete Event Simulation

A very powerful and common approach for the mathematical modeling of supply chains are discrete simulations models (DES). They provide a basis for an accurate description of the underlying process. The main idea of these models is to track goods from origins (suppliers) to destinations (customers). From a mathematical point of view to track means to compute arrival times of each good over the network. Clearly, these times are dependent on the current customer demand and the order policies used of the suppliers. This behavior can be described in a mathematical framework. To provide a concise treatment we state the assumptions on the flow of goods used in the subsequent sections:

1. No goods are lost or gained during the production process. The products can be altered.

2. Each supplier has a fixed processing rate measured in production quantity per unit time and a maximal processing capacity.
3. Buffers or inventories are used to store goods.
4. We consider a dynamic production process.
5. The output of one supplier is fed into the next supplier.

To derive a first model we consider a particular simple situation, see (Armbruster et al., 2006) for more details, on the derivation: a serial supply chain consisting of M suppliers. Here, each supplier m ships all its goods to the next supplier $m+1$ as in Figure 1. Basically, every supplier is now characterized by the parameters, processing time $T(m)$ and, maximal processing rate $\mu(m)$. Here, the processing time $T(m)$ is the time which is needed to finish a single production stage. It is assumed that each supplier is available at all times and there will be no shut-downs. Since suppliers may have different processing rates, it may happen that goods have to wait until the next operations can be performed. Therefore, buffers are installed between the suppliers. In our approach the buffers have unlimited capacity. We treat the problem of limited capacities later. The time-dependent movement of goods is now determined by calculating the arrival times at all suppliers. We define the arrival time of one good n at the buffer of supplier m as a_n^m where the total amount of goods in the system is denoted by N. Additionally, we denote by b_n^m the release time, that is the time that a part n is fed into the supplier m and hence leaves the buffer. Furthermore, the leaving time e_n^m is the time that a good n leaves supplier m and arrives at supplier $m+1$, see Figure 1 and (Armbruster et al., 2006).

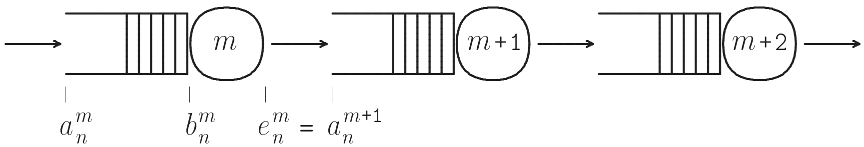

Fig. 1. A serial supply chain.

Goods are selected from the buffers while obeying a certain policy. The simplest policy is given by the FIFO (First In First Out)-strategy. Obviously, the computation of release times b_n^m is dependent on the actual buffer-size which is characterized by only two cases: either the buffer is empty or not. If the buffer is empty, part n is immediately passed into supplier m and $b_n^m = a_n^m$. Otherwise, the part n has to wait and the waiting time is determined by the inverse of the processing rate. Summarizing, the release times are given by

$$b_n^m = \max\left\{a_n^m,\, b_{n-1}^m + \frac{1}{\mu(m)}\right\}. \tag{1}$$

Due to our assumption, we have that the processing time is $T(m)$. Therefore, the leaving time e_n^m is the processing time plus the time the good has arrived, i.e.,

$$e_n^m = b_n^m + T(m). \tag{2}$$

The last assumption guarantees that the part is fed into the next supplier after successful production and hence, $e_n^m = a_{m+1}^n$. Finally, we obtain a time recursion for the computation of all arrival times, see Figure 1.

$$e_n^m = \max\left\{a_n^m + T(m),\, e_{n-1}^m + \frac{1}{\mu(m)}\right\} \quad m = 0, 1, \ldots, \quad n \geq 1. \tag{3}$$

For the evaluation of the time recursion (3) we use curves of cumulative counts, so-called Newell-curves, as already successfully applied in traffic engineering, see (Newell, 1993) . The idea of Newell-curves $U(m,t)$ is to sum up all goods that have arrived at supplier m up to any fixed time t.

$$U(m,t) = \sum_{n=0}^{\infty} H(t - e_n^m), \quad m = 0, \ldots, M, \quad t > 0 \tag{4}$$

where

$$H(t - e_n^m) = \begin{cases} 0, & \text{if } t < e_n^m \\ 1, & \text{if } t \geq e_n^m \end{cases}.$$

In other words, the Newell-curve $U(m,t)$ yields the total number of parts passing from supplier $m-1$ to supplier m up to time t. The difference of two consecutive Newell-curves yields the number of parts actually processed in supplier m (including the goods in the buffer). This difference is well-known as Work In Progress (WIP) and is denoted by $W(m,t)$.

$$W(m,t) = U(m,t) - U(m+1,t), \quad m = 0, \ldots, M-1. \tag{5}$$

Although DES models reflect the most accurate way of modeling a supply network, the computational effort is extremely high in particular for a large number of goods. Therefore, we present an alternative simulation approach based on DES and using continuous equations. We also refer to a comparison of computing times for large scale systems.

The Continuous Supply Network Model

Continuous models are used to describe many physical problems as for example traffic flow on road networks, gas transportation through pipelines, telecommunications networks, drinking water systems and many more. In the context of supply chains, we derive a continuous model which is computationally feasible and accurately describes the dynamic behavior of the system. The presented approach is reasonable in the situation of a large number of parts and can be derived formally from the DES presented above, see (Armbruster et al., 2006).

Therein, a detailed analysis of equation (3) is given and used to deduce a model consisting of continuous equations. This model serves then as a basis for extensions to more general supply chains. We present the final continuous network model for supply chains, as stated in (Göttlich et al., 2005/2006).

We give a definition of a supply network and explain the different scenarios.

Definition 1. *A supply network is a directed graph* $(\mathcal{V}, \mathcal{A})$ *consisting of a set of arcs* $\mathcal{A}$ *and a set of vertices* $\mathcal{V}$*. Each supplier is mapped on to one arc. The length of the supplier corresponding to arc* $e \in \mathcal{A}$ *is given by the interval* $L^e = [a^e, b^e]$*.*

The maximal processing rate μ^e and the processing velocity $v^e := L^e/T^e$ of each supplier are constant parameters on each arc. According to the assumption that each supplier possesses a buffer, we locate the buffer at the vertex v in front of the supplier. For a fixed vertex v, the set of ingoing arcs is denoted by δ_v^{in} and the set of outgoing arcs by δ_v^{out}. In the case of more than one outgoing arc, we introduce distribution rates $A^{v,e}(t)$, $v \in \mathcal{V}_d$, where $\mathcal{V}_d \subset \mathcal{V}$ denotes the set of dispersing junctions, cf. Figure 2. Those rates describe the distribution of incoming parts among the outgoing suppliers and are later subject to optimization. The functions $A^{v,e}$ are required to satisfy $0 \leq A^{v,e}(t) \leq 1$ and $\sum_{e \in \delta_v^{out}} A^{v,e}(t) = 1$ for all times $t > 0$.

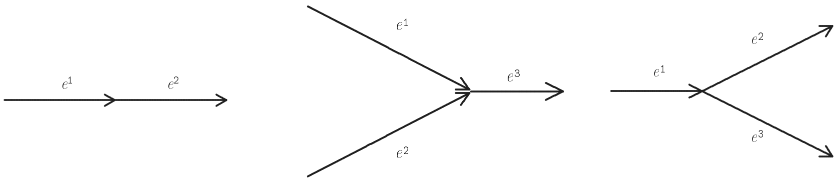

Fig. 2. Possible types of intersections in the network labeled as ordinary, merging and dispersing nodes (from left to right).

Next, we introduce the continuous supply network model which consists of a coupled system of differential equations. These kind of equations arise whenever the relationship between changing quantities (modeled by functions) and their rates of change (expressed as derivatives) is known. This relationship can be derived from the DES, see (Armbruster et al., 2006).

The continuous model describes the evolution of the density of goods $\rho^e(x,t)$ at x in time t inside each supplier e and the time evolution of the buffer $q^e(t)$ belonging to supplier e. On each arc e, the density $\rho^e(x,t)$ is transported with velocity v^e, if the flux of goods is less than the maximal processing rate, i.e., ρ^e satisfies the transport equation

$$\partial_t \rho^e + \partial_x f^e(\rho^e) = 0, \tag{6}$$

where the relation between flux and density is given by

$$f^e(\rho^e) = v^e \rho^e.$$

Whenever a supplier is connected to another supplier of possibly different processing rate μ^e, we introduce a buffering zone for the incoming but not yet processed goods. To describe the buffering we introduce the time–dependent function $q^e(t)$ describing the load of the buffer at time t.

$$\partial_t q^e(t) = A^{v,e}(t) \sum_{\bar{e} \in \delta_v^{in}} f^{\bar{e}}(\rho^{\bar{e}}(x_v^{\bar{e}}, t)) - f^e(\rho^e(x_v^e, t)) \tag{7}$$

The dynamics of the buffering is governed by the difference of all incoming and outgoing goods at the connection point x_v: If the queue is empty, the outgoing flux is either a percentage of the sum of all incoming fluxes given by $A^{v,e}(t)$ or the maximal processing rate μ^e. In the first case the buffer remains empty, in the second case the buffer increases. Last, if the buffer is full, the buffer is always reduced with a capacity determined by the distribution rates $A^{v,e}$ and the capacities of the connected arcs.

$$f^e(\rho^e(x_v^e, t)) = \begin{cases} \min\{A^{v,e}(t)\Big(\sum_{\bar{e} \in \delta_v^{in}} f^{\bar{e}}(\rho^{\bar{e}}(x_v^{\bar{e}}, t))\Big), \mu^e\}; & q^e(t) = 0 \\ \mu^e; & q^e(t) > 0 \end{cases} \tag{8}$$

Finally, we obtain the continuous supply chain model for the evolution of $(\rho^e, q^e)_{e \in \mathcal{A}}$ on the network $(\mathcal{V}, \mathcal{A})$ by equations (6), (7) and (8). The implementation of this model is done by applying standard numerical schemes, see e.g. (Göttlich et al., 2005). So far, the proposed continuous model is based on only a few assumptions and thus extendible to more complicated settings. We present a possible extension in the next section.

A Priority-dependent Continuous Network Model

A possible extension of the supply network model introduced is the modeling of order policies as for example time to due-date (also called attributes, the model has been presented in (Armbruster et al., 2004). We give an example in the case of flows of two goods with possibly different due–dates. Furthermore, we assume that the due–date also affects the processing rate: The flow with an earlier due-date have to preferred in the process and the other flow is either only partly processed or has to wait. In this case the product is stored in the buffer. More precisely, we assume the following:

1. Each part is labeled by an attribute which influences the dynamics inside the supplier by a known relation.
2. The distribution from the buffer into the supplier obeys the ordering of attributes.
3. Goods which have to wait are stored in the same buffer.

In contrast to the original supply network model we now consider two equations for the flow of goods. As in (Armbruster et al., 2004) , the value of Y_k denotes the priority of attribute of product k. Lower values correspond to earlier due–dates and therefore higher priorities. If at some point in time we have $Y_1 < Y_2$, then we obtain the equations for suppliers $e \in \mathcal{A}$ and $k = 1, 2$:

$$\partial_t \rho_k^e + \partial_x f_k^e(\rho_k^e) = 0, \tag{9}$$

$$\partial_t(\rho_k^e Y_k) + \partial_x(f_k^e(\rho_k^e) Y_k) = 0, \tag{10}$$

with the following definition of $f_k^e(\rho_k^e)$:

1. If $\mu^e < \rho_1^e v_1^e$, then $f_1^e = \mu^e$ and $f_2^e = 0$.
2. If $\rho_1^e v_1^e < \mu^e < \rho_1^e v_1^e + \rho_2^e v_2^e$, then $f_1^e = \rho_1^e v_1^e$ and $f_2^e = \mu^e - \rho_1^e v_1^e$.
3. If $\rho_1^e v_1^e + \rho_2^e v_2^e \leq \mu^e$, then $f_k^e = \rho_k^e v_k^e$, for $k = 1, 2$.

The first equation in (9) describes the transport of goods for each attribute through the network, analogously to (6). Additionally, the second equation, specifies the evolution of the order policy subject to the behavior of the flow of goods. In the case $Y_1 > Y_2$ the flows f_1 and f_2 have to be interchanged.

The dynamics of the buffers $q_k^e(t), k = 1, 2$ is given by

$$\partial_t q_k^e(t) = A^{v,e}(t, y) \sum_{\bar{e} \in \delta_v^{in}} f_k^{\bar{e}}(\rho_k^{\bar{e}}(x_v^{\bar{e}}, t)) - f_k^e(\rho_k^e(x_v^e, t). \tag{11}$$

We remark that the distribution rates $A^{v,e}(t, y)$ are now not only time-dependent but also priority-dependent. For the definition of the outgoing fluxes $f_k^e, k = 1, 2$ in equation (11) we state the following case distinction for $Y_1 < Y_2$ and analogously in the opposite case.

1. If $q_1^e(t) \neq 0$ or if $A^{v,e}(t, y) \sum_{\bar{e} \in \delta_v^{in}} f_1^{\bar{e}} \geq \mu^e$, then $f_1^e = \mu^e$ and $f_2^e = 0$.
2. If $q_1^e(t) = 0, q_2^e(t) \neq 0$ or if $A^{v,e}(t, y) \sum_{\bar{e} \in \delta_v^{in}} f_1^{\bar{e}} + f_2^{\bar{e}} \geq \mu^e > A^{v,e}(t, y) \sum_{\bar{e} \in \delta_v^{in}} f_1^{\bar{e}}$, then $f_1^e = \rho_1^e v_1^e$ and $f_2^e = \mu^e - \rho_1^e v_1^e$.
3. If $q_1^e(t) = q_2^e(t) = 0$ and if $A^{v,e}(t, y) \sum_{\bar{e} \in \delta_v^{in}} f_1^{\bar{e}} + f_2^{\bar{e}} \leq \mu^e$, then $f_k^e = \rho_k^e v_k^e$, for $k = 1, 2$.

We offer the following interpretation of these cases:
If there are already high priority goods stored in the buffer or if the flow of goods of priority Y_1^e is already exceeding the maximal processing rate μ^e, then only these goods are processed and all others are not moved (Case 1). If there are only low priority goods stored in the buffer or if there is still some capacity left in the supplier after processing all goods of higher priority, then as much as possible of the lower priority goods are processed $f_2^e = \mu^e - \rho_1^e v_1^e$ (Case 2). Finally, if the buffer is empty and there is sufficient capacity to process goods of either priority, this is done (Case 3). We emphasize that it is sufficient to state the above cases, since for $Y_1 > Y_2$ the roles of f_1^e and f_2^e have to be exchanged. The supply chain model incorporating policy orders can be easily generalized to situations with K different attributes, see (Armbruster et al., 2004).

Advantages and Disadvantages of Continuous Models

Continuous models are used in the economic literature for many years, see (Baumol, 1970; Forrester, 1964). For modeling purposes we will highlight advantages and disadvantages of such an approach. The main advantages of continuous models are:

- The time-varying (dynamic) behavior of the supply chain is described very accurately.
- Since continuous models do not dependent on the amount of individual goods, they allow for fast computing times even for large number of parts.
- Continuous models provide an opportunity to introduce non-linearities in a straightforward and consistent way into these models and to treat non-linear problems like chemical production by appropriate methods.

Whereas the following arguments are recognized as disadvantages:

- It is very difficult to include discrete decision rules such as bounded buffers, maintenance intervals, location of facilities and so on into a continuous framework.
- Optimization problems are difficult to solve due to the continuous constraints.

Optimization of Continuous Supply Chain Models

The Optimal Control Problem

A fundamental question arising in the context of SCEM is the design of 'optimal' supply networks. Depending on the actual application several aspects are of importance:

- Inventory costs
- Storage limitations
- Distribution of goods, materials, commodities
- External supply and demand

In this work, we concentrate on the optimal routing of goods through the network in order to achieve maximal output at minimum cost and further constraints.

The formulation of an optimization problem is based on the continuous model presented above. We derive a formulation which is suitable for commercial optimization solvers. More precisely, the reformulation of the continuous model into a mixed-integer formulation is based on a two-point discretization of each arc e of the differential equation (6). This is possible, since there are no non–linear effects inside a supplier and the movement of goods is carried out in only one direction.

We discretize the continuous problem by introducing a grid in time and space where the time horizon is $\mathcal{T}$ with time steps t. For each fixed arc $e \in \mathcal{A}$ we introduce two variables for the flux at the boundary and a single variable for the buffer at each time t:

$$\mathrm{f}_t^e := f^e(\rho^e(a^e,t)), \quad \mathrm{g}_t^e = f^e(\rho^e(b^e,t)), \quad \mathrm{q}_t^e := q^e(t)\ \forall e,t. \tag{12}$$

Then, the transport (6) equation can be rewritten as a set of linear constraints:

$$\mathrm{g}_{t+1}^e = \mathrm{g}_t^e + \frac{\Delta t}{L^e} v^e \left(\mathrm{f}_t^e - \mathrm{g}_t^e\right), \quad \forall e,t. \tag{13}$$

Binary variables come into play when the nonlinear equation (8) is transformed into a linear constraint. We have to introduce one additional binary variable $\zeta_t^e \in \{0,1\}$ for each supplier and time step. We prescribe $\zeta_t^e = 1$ if $\mu^e < \frac{q}{\epsilon}$ and $\zeta_t^e = 0$ if $\mu^e > \frac{q}{\epsilon}$. In the case of $\mu^e = \frac{q}{\epsilon}$ the binary variable can be either 0 or 1.

$$\mu^e \zeta_t^e \le \mathrm{f}_t^e \le \mu^e, \tag{14}$$

$$\frac{\mathrm{q}_t^e}{\epsilon} - M\zeta_t^e \le \mathrm{f}_t^e \le \frac{\mathrm{q}_t^e}{\epsilon}, \tag{15}$$

$$\mu^e \zeta_t^e \le \frac{\mathrm{q}_t^e}{\epsilon} \le \mu^e(1-\zeta_t^e) + M\zeta_t^e, \tag{16}$$

where M is a sufficiently large constant. To be more precise, M may be set to $\frac{T}{\epsilon} \max_{e\in\mathcal{A}} \mu^e$.

Next, we need to reformulate the coupling conditions (7). We introduce variables h_t^e for the total inflow to arc e at $x = a^e$ and require the following equalities for each vertex $v \in \mathcal{V}$:

$$\sum_{e\in\delta_v^{out}} \mathrm{h}_t^e = \sum_{e\in\delta_v^{in}} \mathrm{g}_t^e, \quad \forall v,t \tag{17}$$

$$\mathrm{q}_{t+1}^e = \mathrm{q}_t^e + \Delta t\left(\mathrm{h}_t^e - \mathrm{f}_t^e\right), \forall e,t. \tag{18}$$

It is a matter of simple calculations after solving the model to recover the entries of the distribution vectors $A_t^{v,e}$ from the values of h_t^e. Moreover, according to the maximal processing rates of the suppliers, we have the following box constraints $\forall e,t$:

$$0 \le \mathrm{f}_t^e \le \mu^e, \quad 0 \le \mathrm{g}_t^e \le \mu^e, \quad 0 \le \mathrm{q}_t^e. \tag{19}$$

The cost functional is chosen in order to be consistent with the aspects mentioned in the beginning of this section. We propose the minimization of production costs c_t^e and inventory costs d_t^e for each supplier and time period:

$$\min_{A_t^{v,e}} \sum_{t\in\mathcal{T}} \sum_{e\in\mathcal{A}} \left(c_t^e \mathrm{g}_t^e + d_t^e \mathrm{q}_t^e\right) \tag{20}$$

Other, user-defined, objective functionals can be envisioned and in the case of a nonlinear costs, we might have to introduce additional binary variables to obtain a mixed-integer approximation, see for example (Fügenschuh et al., 2006). Then, the the mixed-integer model derived by discretization of the network formulation of the supply chain dynamics is as follows:

$$\begin{aligned} &\min\ (20) \\ &\text{subject to } (13), (14), (15), (16), (17), (18), (19). \end{aligned} \tag{21}$$

Remark 1. The mixed-integer problem (21) consists of $3 \cdot |\mathcal{A}| \cdot |\mathcal{T}|$ real and $|\mathcal{A}| \cdot |\mathcal{T}|$ binary variables.

We conclude this section with the following remark: In the particular case of a supply chain consisting of a linear sequence (without branches), there is no possibility to distribute parts. In this case, the mixed-integer model coincides with the two-point discretization of the differential equation and both yield the same dynamics. The mixed-integer problem reduces to a feasibility problem.

Possible Extensions of the Optimization Problem

In general, real-world applications require more sophisticated constraints. We propose a few extensions to the basic mixed-integer model (21) on arbitrary networks.

1. **Finite size buffers:** Usually, in the design of supply chains, it is mandatory to limit the size of the inventory or buffers q_t^e. This condition can be implemented in the mixed-integer context by adding box constraints as follows:
$$\mathrm{q}_t^e \leq \text{ const }, \ \forall e, t. \tag{22}$$
2. **Optimal inflow profile:** Under the assumption of limited storage, the question arises to find the maximum possible inflow of goods and other requirements to the network, such that the buffering capacities of the buffers are not exceeded and the total demand will be satisfied.
This can be modeled by replacing the cost functional (20) by the following objective function
$$\max \sum_{t \in \mathcal{T}} \sum_{e \in \mathcal{A}'} \mathrm{f}_t^e, \tag{23}$$
where $\mathcal{A}' \subset \mathcal{A}$ is the set of all inflow arcs of the network.
3. **Supplier Shut-Down due to maintenance:** Maintenance and repair of suppliers can also be included in the mixed-integer model: Assume that supplier $\tilde{e}$ has to be switched off for maintenance for N consecutive time intervals. Further assume that this period can be chosen freely during the whole simulation time $\mathcal{T}$. Then, we supplement the mixed-integer model with the following condition

$$\mathrm{h}_{t+l}^{\tilde{e}} \leq \max\{\mu^e : e \in \mathcal{A}\}|\mathcal{A}| \cdot (1 - \phi_t^{\tilde{e}}), \forall t, \forall l = 0, \ldots, N-1, \quad (24)$$

$$\sum_{t \in \mathcal{T}} \phi_t^{\tilde{e}} = 1, \quad (25)$$

where for each supplier $e \in \mathcal{A}$ and every time t we introduce a binary variable $\phi_t^e \in \{0, 1\}$ that indicates whether process e is shut-down at time t. If $\phi_{t_0}^{\tilde{e}} = 1$, then the maintenance interval starts at time t_0, and in the time interval $t_0, t_0 + N$, the processor $\tilde{e}$ is not available.

Computational Results

Simulation Results

In this section, we present numerical results for the continuous supply network model. For the simulation of the continuous model discretization techniques are applied which are implemented in MATLAB (MATLAB, www.mathworks.com).

Results on the Priority Model

This test example shows simulation results for the priority model. For simplicity, we consider a sequence of three suppliers characterized by their processing rates $\mu^1 = 110, \mu^2 = 130$ and $\mu^3 = 90$, respectively. The total simulation time is $T = 100$ time units. We suppose that goods labeled by attribute 2 have higher priority (i.e., an earlier time to due-date) in the first half of the simulation. In the second half the situation changes and goods with attribute 1 have higher priority. Goods are periodically delivered into the system. Determined by the processing rates we have two possible bottlenecks: supplier 1 and supplier 3. This fact can be seen in Figure 3.

In Figure 4, an illustration of the flow labeled by attribute 2 in space and time is shown. The flow of the first supplier corresponds to the strip $0 \leq x \leq 1, t \geq 0$, the flow of the second supplier to $1 \leq x \leq 2, t \geq 0$, and so forth. According to the periodic supply and demand and the predefined due-dates, one observes an alternating behavior of the flow over the whole network. More detailed, the on-and-off switches of suppliers in certain time intervals are determined by the flow of goods arriving. If there is flow arriving the supplier tries to work on its maximal processing rate. This explains the plateau shaped network flow. In situations where the flow labeled by attribute 1 is preferred (after $t \geq 50$) we observe an increase of the low priority flux in the third buffer since this supplier only works with a small processing rate. This effect also arises in Figure 4 where the low priority flow is completely interrupted at the third supplier.

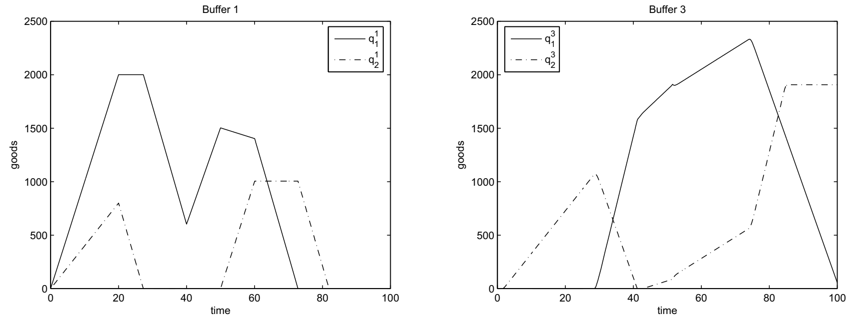

Fig. 3. Amount of goods stored in buffer 1 (left) and in buffer 3 (right). Buffer 2 remains empty since the processing rate of this supplier is large enough to handle all arriving goods.

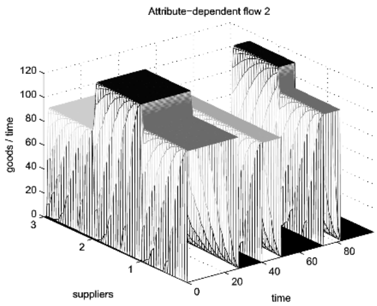

Fig. 4. Time-evolution of the attribute-dependent flow 2 through the network.

Results on Computing Times

We show the computational efficiency of the continuous supply network (shortly PDE) model in comparison with the DES model. We present computing times for varying the size of the network and the amount of goods for a fixed time horizon. Since the continuous model is independent on the number of goods in the system, there is only one evaluation for the continuous model for each increase of suppliers. The total computation time of the DES model (3),(4) is split among two evaluations. On the one hand, less time ($< 1\%$) is used to compute the entries of the matrix $A_{m,n} = (e_n^m)$ in (3). The evaluation of (3) by Newell-curves (4), on the other hand, takes up the most computing time. Here, we further observe that more than 90% of the total time is consumed by computing the Newell–curves. In Table 1, we observe that solving the continuous model is more efficient in all parameter settings. This is particularly underlined for the case of $M = 100$ suppliers where the PDE model is solved just under one minute and the DES model needs more than 23 minutes. The quality of solutions is the same for large values of N.

Model	Parameters		CPU time
DES	$M = 10$	$N = 20\,000$	8.84 sec
DES		$N = 200\,000$	1.56 min
PDE			5.57 sec
DES	$M = 50$	$N = 20\,000$	57.18 sec
DES		$N = 200\,000$	11.92 min
PDE			28.02 sec
DES	$M = 100$	$N = 20\,000$	2.02 min
DES		$N = 200\,000$	23.65 min
PDE			57.09 sec

Table 1. CPU times for a network consisting of M suppliers, N goods and $N_T = 400$ time periods.

Optimization Results

Instances of the mixed-integer problem are described using the modeling language Zimpl (Koch, 2004) , and solved with CPLEX v10.0 (ILOG CPLEX, www.cplex.com) using default settings.

A Large Scale Supply Chain

This example consists of 418 arcs and 233 vertices. The network is highly interconnected and has four entries and four exists. The graph of the network is depicted in Figure 5. We consider a single product flow and prescribe material flows on the entries. In view of the SCEM we ask for an optimal load of the network over time as well as for a prediction of the time–evolution of the network. For simplicity we assume unlimited buffers. To compare optimal and non–optimized flows in the network we depicted the actual flow on selected arcs of the network. The amount of flow is indicated by bold arc lines. The arcs selected belong to the box in Figure 5. To show the dynamics of the network flows we present results at selected times. A simulation result is depicted in Figure 6. In this case the distribution of goods among suppliers is randomly chosen. The load of the arcs and the time–evolution has to be compared with the optimal load of the network. The latter is obtained by solving the optimization problem (21) presented in the previous section. The time–evolution of the corresponding flows is depicted in Figure 7. In both cases the supply network has to process the same number of goods. When distributing with the optimal controls, the parts are moved faster towards possible exists. Therefore, the total load over time is expected to be significantly smaller compared to the non–optimal case. This can be observed in the results. Using the optimal distribution rates the load of the network in the selected area is significantly reduced: For example at time $t = 50$ only a few arcs are currently loaded with parts compared to the fully loaded network in Figure 6. The results shows that in fact complex networks with the continuous dynamics can be optimized and time–optimal distribution rates can be obtained.

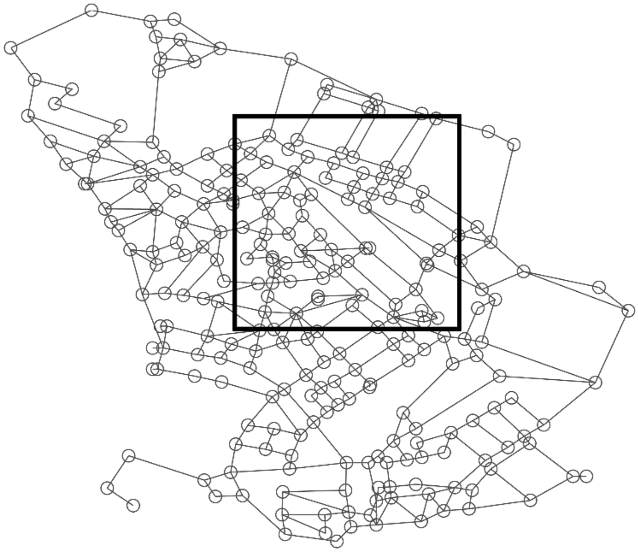

Fig. 5. A supply network consisting of 418 arcs and 233 vertices. The box indicates the clipping area for simulation and optimization results.

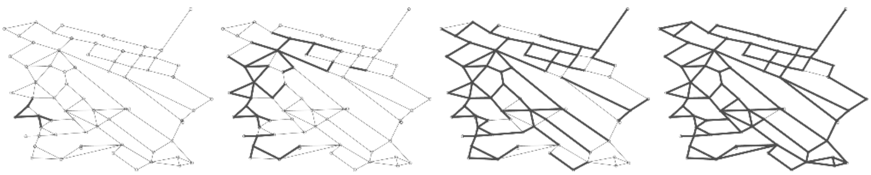

Fig. 6. Simulation results for $t = 10, 23, 36, 50$ (from left to right).

Results on Computing Times

As a further example, we solve the mixed-integer problem (MIP) on connected networks to gain further insights in the computational complexity of our mixed-integer approach. The network we use is a composition of standard

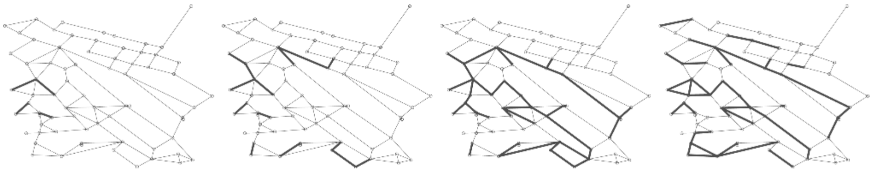

Fig. 7. Optimization results for $t = 10, 23, 36, 50$ (from left to right).

building blocks. Each block has several inflow and outflow arcs such that the flow has to be redistributed at each vertex. We consider networks of $k \times 3$ interior network vertices, where k runs from 1 to 7. An illustration of such a block network is given in Figure 8.

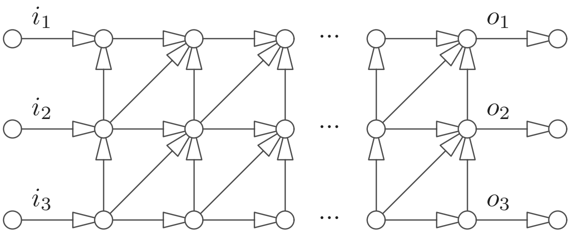

Fig. 8. $k \times 3$ block network.

The values L^e, v^e, μ^e are set to 1 for all suppliers except the inflow arcs $i_1, \ldots, i_3$. Here, we choose maximal processing rates of $\mu^e = 100$. The total time horizon is $T = 8$ time units. For different sizes of networks, $k \in \{1, \ldots, 7\}$, we evaluate the preprocessing and the total solution time for solving the corresponding MIP model. The results are given in Table 2. Clearly, the larger the network, the more time is needed to compute a globally optimal solution. Further, this test shows the behavior of solution times for large problem instances. It can be seen that both times consumed by CPLEX grow with the network size k.

Conclusion

The continuous supply chain model presented is suitable for complicated simulation situations as well as for optimization purposes. Its validity is only given for a large number of parts. Main characterizations for a SCEM are either incorporated (in particular simulation and control) or may be seen during simulation runs (e.g. capacity utilization, availability of commodities). In future work stochastic effects, corresponding to real-world applications, should be included into the model. Moreover, on the discrete optimization level, reason-

k	CPU time [sec]
1	78.87
2	159.09
3	236.59
4	352.08
5	477.50
6	590.09
7	983.55

k	CPU time [sec]
1	105.33
2	201.64
3	332.78
4	555.11
5	810.44
6	1163.25
7	1891.90

Table 2. Preprocessing (left) and solution (right) times in sec for $k \times 3$ block networks.

able user-defined constraints give rise to develop adapted presolve techniques for more efficient computations.

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Design of an Organisational Structure to Govern the Dynamic Behaviour of Aviation-oriented Orders with Multiple Priorities

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Introduction and Initial Situation

I decided to show the foundation of my work by going directly to the source for this project - someone who has to lead one of the frontrunners in the field examined by this work on a daily basis. I am of the opinion that it is easier to win the attention of the reader than simply starting out with a review of previous literature. Thus I present an interview[1] with Mr. Burckhard Schneider - CEO of the German Interturbine Group - which shows the challenges facing aeronautical supply chains. Apart from his position as CEO Schneider is also the owner of Interturbine Logistik GmbH which today is a highly successful company with a turnover of about 45 million Euros as well as Interturbine Transport Service, a forwarding company, and Interturbine Technologies, which manufactures light production parts for aviation. His companies entered a partnership with Airbus to support their worldwide fleet with consumables, chemicals and other spare parts (see also Pfohl a. Trumpfheller, 2005). Furthermore, he founded Lufthansa Technik Intercoat with the partnership of Lufthansa Technik in Hamburg.

Raschid Ijioui: What are the objectives of the company?

Burckhard Schneider: *The company (Interturbine Logistik GmbH) is highly regarded in the global air traffic industry as a result of its delivery reliability and customer service in connection with an extraordinarily varied and highly*

[1] For further details we refer to (Schneider, 2007, pp. 159-164).

complex product portfolio. We have more than 500,000 possible part numbers and specifications. The company combines service elements with above-average delivery speed so that any time-critical requirement is met with a high level of fulfilment worldwide. The company wishes to build on these strengths and expand in the entire area of the transport industry - ranging from air traffic to rail and sea traffic as well as other means of transport.

Raschid Ijioui: What exactly do your customers expect?

Burckhard Schneider: *We are a contractual partner of Airbus, ATR, Eurocopter, Dornier and Embraer. We supply more than 4,000 Airbus models in use, a further 800 ATR aircraft, approx. 11,000 Eurocopter helicopters, around 800 Embraer planes and 300 Dornier aircraft. All these manufacturers expect us to provide international supply management for all maintenance materials. These are materials where the individual items are of comparably low value (also referred to as 'C materials') and which are requested mostly on an ad-hoc basis at various global focal points in very high transaction volumes. As already mentioned, the supply chain (Wassermann, 2004; Geimer a. Schulze, 2005) is very time-critical, which means that aircraft manufacturers demand very high delivery reliability which must be above 98%. This delivery service is measured based on the customer's requirements and the time of provision. The company provides its services as an agent for the aircraft manufacturer for whom it is not economically viable to execute such a high number of individual transactions at a relatively low invoice volume. This is even less viable since approximately half of the deliveries must be made under the proviso that they are executed immediately. Aircraft manufacturers thus expect a level of flexibility and mobility that a major corporation would have difficulty in providing whilst also covering its costs.*

Raschid Ijioui: What significance does the 'time' factor have?

Burckhard Schneider: *Considering that a high-quality aircraft has to cover costs of tens of thousands of US dollars in terms of interest and fixed costs per day, an aircraft cannot afford to endure interruptions in operation.*

Raschid Ijioui: Where do you see the challenges in the coming years?

Burckhard Schneider: *The challenge of the future will be to recognise in good time which materials are required for which maintenance services at which location (see Fig. 1). Various parameters need to be taken into account, including the limited life of materials, lot sizes, delivery times, country-specific requirements and similar. It is thus essential to identify any future demands and thereby plan in advance using storage sites in the global warehouse logistics area so that the relevant materials are available in the region if required and so that any urgent requirements are satisfied promptly.*

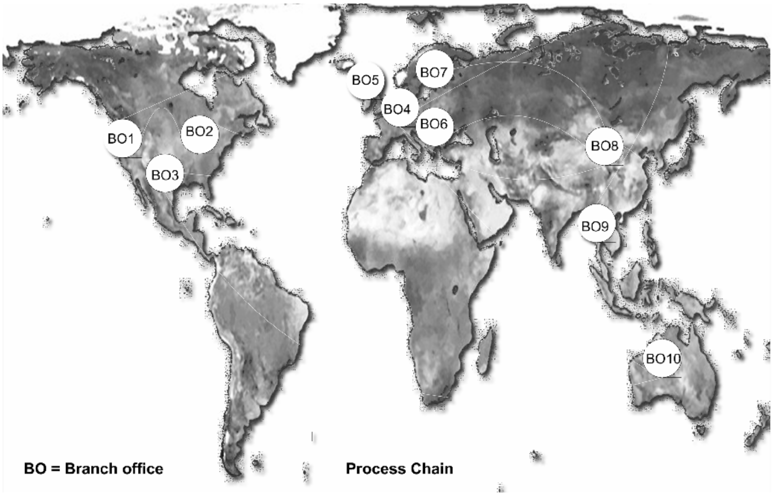


Fig. 1. Time-dependent network of Interturbine Logistik GmbH. Further branch offices are in Czech Republic, South Africa, United Arab Emirates, India and Canada (status 2006).

Raschid Ijioui: What influence does the new Airbus A380 have on the development of your business processes?

Burckhard Schneider: *All the criteria named above play an even bigger role for the new Super Airbus, since this high-investment asset must not suffer any unnecessary idle periods for obvious reasons. The technical systems are designed accordingly. It must now be requested that the materials supply logistics processes expected in future are forward-looking to such an extent that materials supply does not stop due to any logistical misrouting (see also Stölzle a. Karrer, 2004). This also includes new channels in regional logistics as well as access regulations at the airports. In addition to highly proactive planning, any failures must be excluded from the outset by deploying the most effective prevention mechanisms possible.*

Raschid Ijioui: In your opinion, what differentiates air traffic suppliers from other suppliers?

Burckhard Schneider: *The critical mass of materials and materials volume in air traffic are, of course, considerably less. In most cases, the economy of scale can therefore not be compared to the automotive industry, for example. Just-in-time and other concepts can only be used to a limited extent, as experience has shown that at least 50% of all materials requirements are 'Aircraft on Ground (AOG) requirements' (i.e. highly urgent for the operation of critical immediate requirements) which either could not be planned or which have developed as a requirement from unscheduled events. The recipe in this case* *is simply high flexibility, high availability control and a focus on individual requirements in order to provide services that fit the particular situation.*

Raschid Ijioui: How important do you consider a continuous re-engineering concept to be?

Burckhard Schneider: *Re-engineering (Gaitanides, 2006) is becoming increasingly important for the future because this process must accompany the normal business routing process almost continuously. This is due to the fact that the technology for aircraft maintenance and upkeep as well as for other means of transportation advances very quickly and new upkeep procedures and maintenance segmentations are being developed all the time. ... The importance of this becomes clear when you realise that flight cancellations and delays due to then non-availability of maintenance materials quickly causes costs to be that high (idle period costs, depreciation costs, staff costs, possible accommodation costs for flight passengers, loss of reputation etc.) that these are no longer compensated by the flight margin. Even if the number of problems decreases due to higher technical reliability, every negative aspect is still a considerable emotional factor which may indirectly result in significant business losses for the transport operator.*

Raschid Ijioui: You started the following research work in 2004. What positive effects do you hope this 'Interchain' project will have?

Burckhard Schneider: *On the one hand, 'Interchain' ('Interchain' combines the company name (which in turn derived from the international nature of its operation) with a basic component of logistics - the business process chain). represents an opportunity to simulate the business processes and their costs, but on the other hand it also enables us to monitor and control the process route and better distribute and follow up on resources. Since we control the entire process for the customer - from materials planning to all types of commissioning to the delivery at the place of use - it is necessary to obtain a very detailed overview of each process stage. This overview is particularly important where highly sensitive materials are concerned, such as composite construction materials that must still be frozen at minus 18 degrees Celsius when they arrive at the place of use. Consider a delivery from the USA which must arrive frozen in Australia no matter which global route is taken. A temperature recording device is used as evidence, but is of course no 'guarantee' for a smoothly functioning transport chain without waiting times. If this materials shipment were to be held up somewhere, it might result in the material being useless when it arrives at the recipient and, as a consequence, it may not be possible to carry out maintenance work to the aircraft on the scheduled date or a flight might have to be cancelled. This explains the investment in such a project and the desire for increasingly fine-tuned tools so that the delivery service is not only provided until dispatch, but is controlled until it arrives at the recipient and* *ideally until it reaches the aircraft. 'Interchain' enables an overview of the entire service chain and ends when the delivery is handed over to the customer. 'Interchain' is seen as an important tool to further accelerate delivery times, increase delivery reliability and carry out follow-up controls based on timely recognition so that the customer's level of satisfaction finally not just remains the same but even increases. ... In accordance with the statements made so far, a secured supply chain is the essential prerequisite for meeting conditions and the continuously further developing requirements of aircraft maintenance. ... The combination of all criteria, all process stages (Schlick a. Killich, 2006; Castells, 2004) and the overview of each individual business transaction makes it possible to have an 'on-time' service production process with 'Interchain', so that this tool, in conjunction with the supply coverage of the 'one-stop-source' concept, enables uniqueness with regard to the global supply of C materials. 'Interchain' is the global control function for all materials movements with the aim of meeting almost 99% of all requirements.*

Raschid Ijioui: Many thanks!

Preliminary Resume

As we have seen, airline suppliers have to work under tremendous pressure in order to be able to continue to compete in the global market. Because of this pressure, they are forced to reorganise their internal work processes (Tijssen et al., 1996; see also Sames, 1992; Westfechtel, 2001; Petry, 2004) so that they are able to complete their orders within the given deadlines. They are challenged to structure their process chains (Abrahamsson et al., 1998; q.v. Lasson, 2006) respectively processes (Hammer, 2007; Utikal a. Ebel, 2006) in such a way that all orders, no matter how difficult to process, exit the company within the shortest possible amount of time (cf. also Christopher, 1998; Nilsson et al., 2005). Many companies spend enormous amounts of money on outside consulting and attempts to improve the way their business operates. But without a clear notion on the precise nature of the problem facing them, the success of these measures is doubtful. Thus, the real trick of improving business chains is to understand the nature of the problem before attempting to provide any solutions. Only then does it become possible to improve the way a company operates on a realistic budget.

To guarantee the timely delivery to airline companies under all circumstances in the future as well, a theoretically grounded but also praxis-oriented concept has to be developed on the basis of this research work, whose realisation

- guarantees the timely delivery of orders under constantly increasing customer expectations (we refer to the answer to the second question of the interview),
- creates large-scale transparency among the business processes,

- streamlines the organisational interfaces between sections and branch offices.

Background

The rapid technological advances and opening of borders in recent decades have given rise to the modern form of globalisation - and with it, an ever-increasing amount of traffic of both goods and people. The airline industry is at the forefront of these changes. Never before has the air seen so much traffic. Never before have so many airline companies competed to transport passengers and cargo so fast and so cheap. Two gargantuan companies - Boeing and Airbus - whose combined budget is larger than that of many countries - compete fiercely for market dominance, shaped by the politics of their respective companies (see e.g. Braunberger, 2006; Jasvoin, 2006). But neither Boeing nor Airbus exist in isolation, and the same is true for the airline companies who are their customers. It requires a multitude of smaller support companies to keep the air fleets of the world running (see also Pfohl a. Trumpfheller, 2005), and the pressure the airlines feel is passed on to their suppliers and intensified (see e.g. Braunberger, 2006).

To withstand and even prosper under this kind of pressure, these suppliers need to constantly re-examine and improve their business processes. Many companies spend enormous amounts of money on outside consulting and attempts to improve the way their business operates. But without a clear notion on the precise nature of the problem facing them, the success of these measures is doubtful. Thus, the real trick of improving business chains is to understand the nature of the problem before attempting to provide any solutions. Only then does it become possible to improve the way a company operates on a realistic budget.

To achieve this goal, using **modelling** as the initial step of the classical business reengineering (Hammer, 2007; Hammer a. Champy, 2001) cycle is an invaluable aid (see also Bergsmann et al., 2005, p. 50 et seq.; Schweizer, 2005; Deiters, 1997). It helps with the analysis - identifying the precise problems slowing down the company - and it makes both the current and the future, improved business processes understandable even to employees not trained in the intricacies of business reengineering.

However, today's work processes are often so complex that it has become impossible for a single person to truly understand it in all its details. By creating a model with just the right level of abstraction, it becomes possible to gain a systematic understanding of it again (cf. also Bossel, 2004).

Furthermore, most cases of business reengineering face stiff resistance from the employees comfortable with the old process, since they fear change and the uncertainty it brings. Only showing the clear benefits of new approaches with the visual aid of a model will help to convince them (cf. also Hill et al., 1992).

But it should be taken into account, modelling is more than just writing down all steps of all work processes within a company and connecting them. A certain abstraction is vital to make the model truly understandable, but finding just the right level of abstraction is a continual problem - too much, and the model won't capture enough nuances to be a meaningful representation of the process chain; too little, and the model will not be understandable.

For precisely this reason companies prefer external advisors to examine their process chain, as they do not identify with the strongly established daily routine of the company and thus are able to offer fresh perspectives and insights. Bossel describes the challenge as follows:

> "*The best model is one which meets its purpose in full at the lowest possible level of complexity. The model should be as simple as possible but as complex as necessary.*"[2] (cf. Bossel, 2004, pp. 51-52 et seq.)

Additionally the researcher also remarks that

> "*...a one-to-one mapping from system to model in general is impossible (apart from in very simple cases)...*"[3] (cf. Bossel, 2004, p. 52).

For the following research work we used the Petri- (1962) and Function-net (Godbersen, 1983) based Funsoft nets approach by Gruhn (1991; q.v. Deiters a. Gruhn, 1994; Gruhn a. Jegelka, 1992; Godbersen, 1983; Ben-Shaul a. Kaiser, 1995; Oberweis, 1996a/b; Gruhn a. Kampmann, 1996, p. 384) for the visualisation (see e.g. Fig. 3) and the continuum approach (see e.g. Mirowski, 1999; Bossel, 2004; Schütt et al., 1990; Czichos, 2000) for the actual simulation (see chapter 'Simulation of Intra-Organisational Interfaces...'). Initially, I fully intended to use the FunSoft net approach for the entire modelling process as I had extensive experiences with it and expected it to be ideal for this project. The reason is that FunSoft nets can (for example) easily track individual orders within the process chain. However, as time progressed the requirements for the projects were intensified in such a way that using FunSoft nets alone for the modelling proved to be insufficient - tracking individual orders was no longer the prime goal, but examining the total flow of orders was. These requirements incited me to consider a combined approach using tools drawn from the fields of mathematics and physics - a so-called continuum approach (q.v. chapter by Göttlich a. Herty: 'Dynamic Models for Simulation and Optimization of Supply Networks')- with the more familiar FunSoft nets developed and used mostly in the field of computer science.

After starting with an interview and summarizing the fundamentals of 'Business Process Modelling', I will now analyse the as-is situation (Ijioui et

[2] Original: "Das beste Modell ist dasjenige, das seinen Zweck bei geringstmöglicher Komplexität voll erfüllt. Das Modell sollte so einfach wie möglich, aber so komplex wie nötig sein".

[3] Original: "...eine Eins-zu-Eins-Abbildung von System zu Modell im Allgemeinen (ausser in einfachsten Fällen) unmöglich ist...".

al. 2005/2006b) in chapter 'The Initial Business Process of Interturbine'. To examine the effectivity of the process chain, chapter 'Time Data Analysis' evaluated the process shown in 'The Initial Business Process of Interturbine' with the aid of a time data analysis. Due to project constraints, it was not possible to implement a time data analysis with multiple branch offices. Instead, the simulator was developed to help understand the time data in the branch offices and especially examine locally occurring bottleneck situations (chapter 'Simulation of Intra-Organisational Interfaces: Theory of the Simulation Model'). The weaknesses discovered through both simulations and manual analysis are described in chapter 'Findings of the Weak-Point Analysis'. The resulting requirements for the target process are listed in chapter 'Derived Design Requirements'. The foundations of the concept are threefold: A pneumatic delivery system for streamlining internal interfaces between work sections (implemented by Arlt GmbH), the decentralisation of the global network of branch offices, and the implementation of the Interchain system (assisted and realised by the CargoSoft GmbH). The implemented solutions is shown in chapter 'Conceptualised Organisation', and is validated through practical experiences in chapter 'Validation: Valuation of Suitability'. In the following we illustrate the general as-is process of Interturbine Logistik GmbH.

The Initial Business Process of Interturbine Logistik

Each order O_n passes through a chain of processes, with each work process being represented by an individual section S_j $(j \in \{1, \ldots, 6\})$. Within a department s_j, each O_n has the following information.

1. T_{Fin} describes the time left until the deadline for orders with multiple priorities. This determines the priority of the O_n:

$$P(T_{Fin}(O_n)) = \begin{cases} 1: \quad T_{Fin} \leq 1d & (C) \\ 2: 2d < T_{Fin} \leq 3d & (U) \\ 3: 3d < T_{Fin} \leq 7d & (St) \end{cases} \tag{1}$$

   Critical orders[4] (C) are worked on in preference of all others, leaving out parts of individual work processes.
2. C_{px} describes how difficult or time-consuming it is to complete the order at each workspace. In general we can group the orders for materials into three degrees of complexity, with higher-complexity orders taking up far more time to process than lower complexity orders. The following values are used:

$$C_{px}(O_n) = \begin{cases} 1: easy \\ 2: medium \\ 3: difficult \end{cases} \tag{2}$$

[4] This the equivalent of AOG - Aircraft on Ground orders used in the airline.

Which orders fall into which category depend on the individual sections and their work processes - what might be a 'difficult' order for one section might be an 'easy' order for others. For example, the 'customer service' (CS) section might define the different complexities of its work processes as follows:

- $Order_{easy}$: Replacement parts ordered are known to the company and available in its stock.
- $Order_{medium}$: The replacement parts are known to the company, but currently out of stock, and thus need to be ordered from third party suppliers.
- $Order_{difficult}$: The replacement parts are unknown to the company and (obviously) not in stock. The existence of the parts and its suppliers need to be researched first before they can be ordered.

Other sections will define these difficulties differently. For example, the 'Commissioning' section merely groups them by the number of replacement parts that are part of a single order. Especially high-complexity orders are problematic, since they are prone to create bottlenecks by taking up large amounts of time that could easily be used to process lower-complexity (and more profitable) orders. The following figure 2 illustrates one formal process of a sample section of the time based flow of individual orders passing through the different sections S_j.
Section S_j represents the possible location of an order O_n. Each subunit of S_j passes an order O_n that has gone through the local work process on to the next subunit in the same S_j, or to S_{j+1}. Each section S_j is further subdivided into:

3. A distributor D_j: This is the 'waiting room (inbox)' for all O_n that have not been assigned to a specific employee E_{ij} in the workspace yet. It has a data list for all unassigned O_n.
   - It checks the ES of all employees in the subsequent Workspace. It assigns orders to all employees with ES=1. Orders are assigned in order of their priority value, with C getting assigned first and St assigned last. The orders are moved to the active folder of the employees, and the ES switches to ES=2. Within these priority categories the orders are assigned on a first in, first out basis. Any remaining orders stay in the distributor.
   - Any employee who receives a new order immediately gets a randomly determined numerical value (based on real world statistical values and the C_{px}. value of the order) LTFin, which represents the time left until the employee has completed working on the order.
4. A workspace WS_j: This is where the actual employees can be found. Any employees E_{ij} has the following status information:

$$ES_{E_{ij}} = \begin{cases} 1 : idle \\ 2 : WorkingonOrder \end{cases} \tag{3}$$

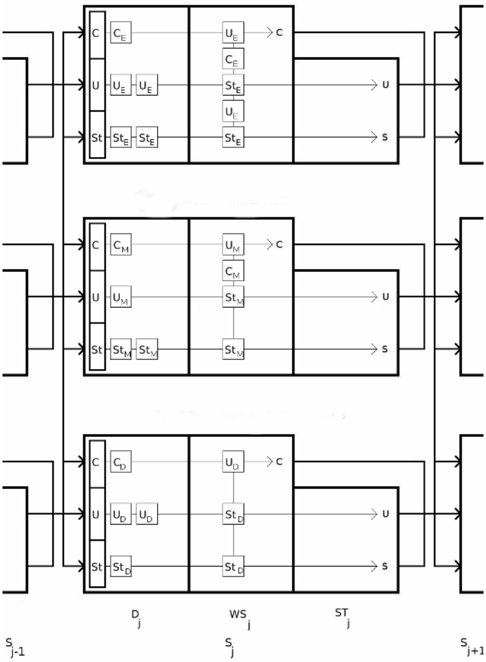


Fig. 2. A sample internal section of the supplier.

5. Storage ST_j: This is the 'waiting room (outbox)' of orders with priority U and St (Eq.1) that have gone through the work process required by the local section, but have not been moved yet to s_j. Each ST unit has a numerical value ST_{Fin} that determines how much time is left until the storage sub-unit is emptied.

In addition to this department-specific information, each order O_n also includes either a package list , a material request list or shipping documents which is moved with the order from department to department. To examine the flow of orders and their accompanying information, we examine the interactions between the departments (Ijioui et al., 2004/2005; Hägele, 2005; Fricke, 2005). The process flow can usually be broken down into two subprocesses A and B:

- **Available (A)**: This covers orders O_n that can be completed based on the stocks available. These orders O_n go through a total of four operational departments s_j ($j \in \{1a, 2a, 3a, 4a\}$):

  s_{1a} : After receiving the order O_n, the s_{1a} employee generates a packing list. This is a document in which the material (item name, etc.) desired by the customer is recorded, similar to a shopping list.

s_{2a} : After the creation of the packing list, the document is passed on to s_{2a} employee who searches for the material desired in the warehouse and pre-packs it. Subsequently, the s_{2a} employee passes the packing list to s_{3a}.

s_{3a} : Based on the packing list, the s_{3a} employee creates the required delivery documents. As each item may have different delivery requirements (for example, some are toxic), each receives a different delivery paper.

s_{4a} : The s_{3a} employee then passes the documents on to s_{4a} for review and consolidation of the documents and materials. This double-checking of the items is vital for accurate delivery.

- **Not available (B)**: These are orders O_n for which an order must be placed. Here an order O_n goes through a total of eight operational departments s_j ($j \in \{1a, 5b, 6b, 5b_2, 1a_2, 2a, 3a, 4a\}$) (some even repeating the process):

s_{1a} : In contrast to point (A) the s_{1a} employee initially creates a material request and provides it to s_{5b}.

s_{5b} : Following a thorough review of the document and checking it for the most efficient ordering process, the s_{5b} employee orders the desired material.

s_{6b} : The selected supplier delivers the material ordered to the s_{6b} employee. Following a check of the material, the s_{6b} employee creates the goods receipt notification and sends it to s_{5b_2} for posting.

s_{5b_2} : The s_{5b_2} department record the received goods in the system and notifies the relevant s_{1a_2} employee that the goods have been received.

s_{1a_2} : After this, the process repeat itself (see point **A**)[5].

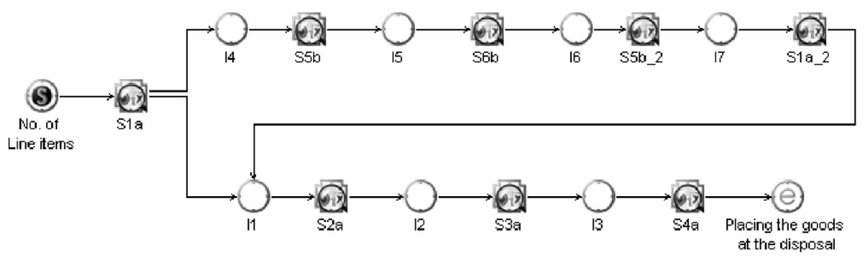


Fig. 3. Macroscopical process flow of Interturbine Logistik GmbH (made with LeuSmart (adesso, 2001)).

So far we have explained the internal process of the company. But if we want to evaluate the effectiveness of the process chain (Abrahamsson et al.,

[5] NB: the packing list is frequently also created by s_{5b}.

1998; q.v. Lassen, 2006), we need to examine the effectiveness of the individual contribution to the overall performance of this process chain. A major contribution is that of the time individual employees require to complete their part of the processing. Kruppke (2007, pp. 152-153), too, emphasises the necessity of determining the time data and points out that knowledge of the cycle time is an essential criterion of

- process planning (Binner, 2004, p. 428 et seq.),
- process benchmarking (Legner a. Österle, 1999, pp. 331-352; Binner, 2004, p. 985 et seq.),
- process controlling (Mühlen, 2004),
- process assessment (Becker, 2007, 57-70; Fischermanns a. Völpel, 2006),
- scheduling (Binner, 2004, p. 551 et seq.) as well as
- continuous process improvement (Binner, 2004; Hill et al., 1992).

With regard to this we will discuss below the results of our time data analysis reported also in (Ijioui et al., 2005, pp. 239-245).

Time Data Analysis

For a more detailed understanding of the importance and necessity of time measurements (Sieper, 1988), we introduce the following process scenario approach (Ijioui et al., 2005, p. 239): An Airbus customer places an order with 36 hours left until the deadline. Since the order is for a large number of replacement parts, processing it at each step of the supply chain is a lengthy task and it takes 11 hours until the order has moved through the customer service department. Subsequently the order passes to the Stock department, where a recent rush of high-priority orders (with a deadline of 25 hours or less) causes it to wait for 30 min. Afterwards the order is assigned to an employee, but since it is late in the afternoon and he had a lot of trouble completing the high-priority orders, he is not quite as concentrated and has to break off working on it after 180 min at the end of his shift. Thus, the order waits for 14 hours until the next morning (idle period), when he completes the order after 30 more min. Now the order has only 7 hours left until the deadline and is thus tagged as a high-priority order. It now moves speedily through the departments without any lengthy waiting periods and it takes 35 more minutes to pass through the Commission department and 25 min until it has been processed by the Final Control department, completing the supply chain with 6 hours left until the deadline.

If we want to measure the process performance of the above scenario, we need to determine the time individual employees require completing their part of the processing. But, one of the most difficult tasks is to obtain accurate process time data (Miehler, 1998). For example,

- employees might fear to raise expectations about their work speeds and thus report longer times than they need to complete their tasks, or

- conversely try to pretend to work faster than they actually do during day-to-day work.
- And some employees might not take the task of recording accurate time data seriously enough (Engelmann, 1995; Hill et al., 1992) and introduce large rounding errors which skew the statistics.

These are just a few examples of the many difficulties (Engelmann, 1995; Hill et al., 1992) likely to appear when attempting to gather accurate data. However, for a company trying to optimise its work processes, gathering such information is a task of vital necessity (Kruppke, 2007, p. 152 et seq.), for only with such information a company will be able to:

- effectively plan newer, improved work process chains (Binner, 2004; Miehler, 1998),
- plan, coordinate and simulate development and work processes (Schlick a. Kausch, 2007; Schlick a. Licht, 2005; Schlick a. Licht, 2007; Banks, 1998),
- reduce personnel costs (q.v. Refa, 1955; Binner, 2004),
- calculate adequate consideration (q.v. Refa, 1955),
- analyse work centre costing (q.v. Refa, 1985),
- identify unobvious weak points (q.v. Miehler, 1998),
- and realistically evaluate future personnel needs (q.v. Refa, 1985; Binner, 2004).

Ideally, one would measure time data for work process steps all the time to get the most accurate data possible. In practice this is not feasible, since recording time data is a time-consuming and exhausting task (Bechte, 1984) that takes ressources from the actual work processes that create the profit for the company. Thus, the time data has to be restricted by necessity to a small but statistically significant data set taken over a shorter period of time. From the thereby collected data, statistical distributions (Bechte, 1984; Sachs, 1999) have to be extrapolated, so that it is possible to create realistic random work times for stochastic simulations of the work process (Holtkamp, 2007). However, a variety of factors, e.g.

- employee fatigue,
- work breaks and
- any of the numerous other interruptions of the daily work life,

conspire to make the distributions of processing times different from the more common probability distribution functions. Thus, the processing times for each department and each order complexity must be analysed individually to find the distribution (Beichelt a. Douglas, 2003; Spiegel, 1992) that fits it best (we refer also to Ijioui et al., 2005, p. 239 et seq.). For our work we analysed the following three relevant economic aspects:

1. How long does it take an employee to complete his sequential work process step for orders of easy, medium, or difficult complexity (including the

minimum and maximum time values of these order complexities, as well as the standard deviation)?
2. How long does an order stay in the department (dwell period)?
3. How much time is required by the interfaces (transition time between the departments and the branch offices[6])?

To record process times, a total of 2000 individual work processes was recorded and analysed with regard to their time requirements during a period of approximately four months (Ijioui et al., 2005; Hägele, 2005; Müller, 2005). As the method of data acquisition we used process slips (see for example Miehler, 1998; Binner, 2004, p. 346 et seq.), which passed from department to department with the orders and on which the employees had to record the time of entry into and the time of depature from their department. In general the investigation showed that the net process time (WS_j in Fig. 2) only takes up 10% of the overall cycle time. The dwell period (D_j and ST_j) and the time spent passing through the interfaces (the arrows in the Fig. 2) take up the remainder (approx. 90%).

Similar results are also indicated by Bechte (1984, p. 11), Stalk (1993a; 1993b; 1993c; 1993d: p. 529 et seq.), Hout and Stalk (1993, pp. 565-568), Istvan (1993, p. 559-564), Frantz (1993, pp. 569-573), Reiner and Ericksen (1993, pp. 588-592), Oetinger (1993) and Miehler (1998).

With regard to these findings, Miehler (1998, p. 4) points out that the

> *"...lever for the reduction of cycle time is not to be found in net processing times".*[7]

For this reason, many researchers recommend focussing optimisation processes on organisational interfaces (Miehler, 1998, p. 4; Horvath, 1991; Brockhoff, 1994; Brockhoff a. Hauschildt, 1993; Fischer, 1993). The influences of internal interfaces (between sections) have already been stated above. As far as the cost-intensive external interfaces (interaction between the branch offices: Fig. 2 can also represent individual stations which can be used for the measurement process. Additional stations precede or follow the one shown in detail.) are concerned, we will analyse them with a PDE-based simulator (see Fig. 5 and see also Ijioui et al., 2007c; Salkovic, 2007).

However, before dealing with the theory of the simulation model and our test results, we will first briefly explain the interaction between the branches and the German main station by way of illustration.

In general the Interturbine Logistik process chain is centrally controlled. This means that all stations (there are special cases, too) must only process

[6] Notabene: we are restricting the measurement to the collaborative process between Germany and Texas. This restriction was necessary as otherwise we would have seriously hindered the entire process chain.

[7] Original: "...Hebel zur Durchlaufzeitverkürzung nicht bei den Bearbeitungszeiten zu finden ist."

any incoming customer orders up to a specific processing step (more specifically, the delivery note and the invoice are always created by the main station and sent from there to the relevant party involved) (cf. Müller, 2005).

The consequence of the procedure is, if USA (Texas) completes its part at a time when the German offices have already closed, it can take up to 14 hours until these offices open up again and the orders can be processed further (q.v. Fricke, 2005). After this, the order passes to the customer service department in Germany. But if there has been a recent rush of high-priority orders (with a deadline of 24 hours or less), even further delays can result, which in combination with other factors (such as overwork and stress on the part of the employees) can push the order closer to the deadline - or beyond it. With regard to the managing director (Müller, 2005), this conservative process "*...has developed as a result of the necessity to monitor the work in the remote stations.*"[8]

After an introduction to the resulting model (see next section) we present the results of our simulation study (see section: Results of the Simulation) (q.v. Ijioui et al., 2007c).

Simulation of Intra-Organisational Interfaces: Theory of the Simulation Model

Traditionally, these or similar processes are being modeled by tracking individual units throughout the system, for example by using a cellular automaton-style (CA) algorithm model (Ijioui et al., 2006b, pp. 70-73 see also Emmerich a. Rank, 1997; Emmerich, 1997; Wei et al., 2003; Crutchfield a. Hanson, 1993; Frisch et al., 1986; Jerome H. Abrams et al., 2000) or Petri net based models (see for example Deiters a. Gruhn, 1998; Erdmann a. Wortmann, 1997; Fricke, 2005; Gruhn, 1991; Jensen, 1997; Aalst, 1998). For more detailed understanding, I want to showcase the cellular automaton-style algorithm model (Ijioui et al., 2006b, pp. 70-73) as a general example (for more complete definition of CA see Wolfram, 1984/1986):

In such a model, each order represents a cell, which can be in the state S: $\{1, 2, 3, 4, 5, 6, 7\}$ according to the definition of T_{Fin} (see equation 1). As fulfilling orders is a linear problem, the automaton is one-dimensional and the considered neighbors reduce to one. A finite number of new orders is generated in each time step which is taken to be one day in real life. Orders which are fulfilled will be deleted at the end of each time step. Therefore, the automaton's size can vary at every time step, because the number of orders M which can be fulfilled in one time step is fixed (see equation 1). Where T_{Fin} is the time left until the deadline, expressed in days $[d]$. Orders are created setting a cell's value to the number of remaining days until the order must be

[8] Original: "...aus der Notwendigkeit entstanden, Kontrolle über die Arbeiten in den Aussenstationen auszuüben."

fulfilled. If an order is not fulfilled at the end of one time step, its value will be decreased by one. If the order reaches a value of zero, it will be set back to one and a counter representing the amount of failed orders is increased. This corresponds to the fact that the owner of the supply chain (Christopher, 1998; Neo et al., 2004; Daganzo, 2003; Helbing, 2003) has to pay for every order he fails to fulfill. A cell i can only be considered if its state $s(i)$ is lower than its successors state $s(i+1)$. But there is always the possibility that an order cannot be fulfilled in a time step depending on the value of barrier parameters like the "certification error" E_c (implying that the material cannot be proccessed further) or the "storage error" E_s (the product connected to this order is not on stock) and the "human error" E_h. Each parameter inhibits with a stochastic probability that the order can be fulfilled. Thus, the transfer function δ resolves to:

$$\delta : s(i) \longrightarrow s^*(i, s(i+1), M, E_c, E_s, E_h) \tag{4}$$

The user can define the distribution of order types and the values of the barrier parameters as an input for the simulation.

However, here we attempt to model the network without tracking individual units, but by looking at the flow of orders as a whole by developing a PDE (Partial Differential Equations) model. This is not without precedence, as Mirowski (1999), Schütt et al. (1990), Czichos (2000) and Bossel (2004) demonstrated that equations used in physics can be used to create models suitable for economic phenomena (Sterman, 2006). This is analogous to a flow of liquids through a pipe system where one drop of liquid is identical to any other (see Fig. 4: similar models see also Bossel, 2004; Plossl, 1983, p. 44 (cited by Wiendahl, 1987); Wiendahl, 1989/1991; Kulkarni, 1997), but the thrue point of interest is how fast the liquid flows, and where it will build up dangerous pressure. In the following we describe the PDE model which is based on the work process of our industry partner.

The amount of orders at each section $S_{j,l}$ are defined as:

- $C_{j,l}$: critical orders
- $U_{j,l}$: urgent orders
- $St_{j,l}$: standard orders

Note: l stands for the location of the branch office.

While in reality the amount of orders at each section will be in whole numbers, for the purpose of this model the number of orders is abstracted and can take any value, including fractional ones. Since the approach is not intended to examine short-term (and essentially random) fluctations, it 'averages' the number of orders and only calculates the gradual build-up of the 'pressure' on each section. There, pressure applies to the likelihood of failure to meet time demands in reality. If we adhere to the 'pipe model', each type of priority represents a different type of liquid in three separate 'basins' at each section (see Fig. 4). Each can hold a theoretically infinite amount of liquid orders but

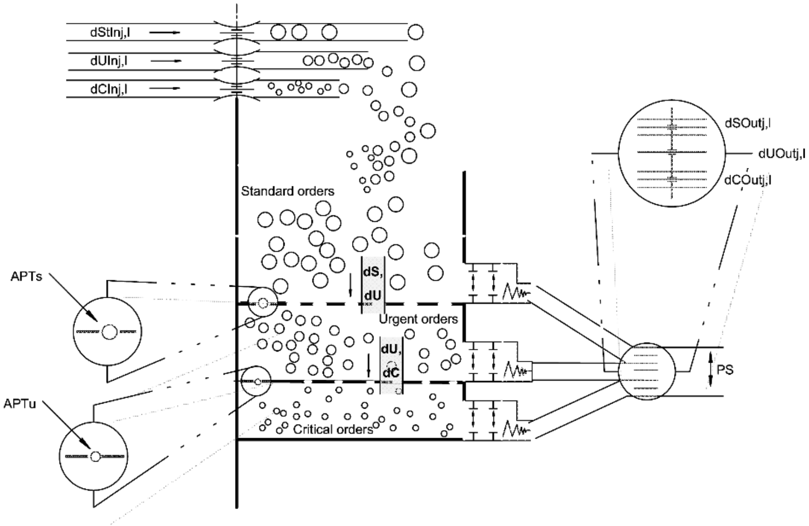


Fig. 4. Metaphorical representation: The flow of orders PDE model.

ideally the company can keep the amount of liquids at each section as small as possible to keep the work process going smoothly and avoiding unnecessary waiting periods - while still making sure that the work capacity of each employee is used to its fullest potential.

During each time step dt, the PDEs are updated according to the following scheme:

1. **Change of order priority**
   Orders within a time-sensitive process chain will change priority as the deadline approaches. To simulate this, we derive equations inspired by standard equations used for radioactive decay (which also represent approximations of essentially stochastic processes).

$$APT_s = \frac{\sum_n (TFIN_{s,Init}(O_n) - 72h)}{n} \tag{5}$$

$$APT_u = \frac{\sum_n (TFIN_{u,Init}(O_n) - 48h)}{n} \tag{6}$$

   Within these equations the following definitions are used:
   APT_P: Average time an order with priority P will stay at that priority, assuming that the order will not be completed before switching to a higher priority.

$TFin_P$, Init: The time an order has left until the deadline when it initially reaches priority P, whether it has reached priority P from a lower priority, or entered the process chain with that priority in the first place.
(Note: While it is possible to calculate APT_C, this value is not required for the calculations.)
The APT values influences the amount of orders at each priority over time:

$$\frac{dC_{j,l}}{dt} = +\frac{U_{j,l}}{APT_U} \tag{7}$$

$$\frac{dU_{j,l}}{dt} = +\frac{S_{j,l}}{APT_S} - \frac{U_{j,l}}{APT_U} \tag{8}$$

$$\frac{dS_{j,l}}{dt} = -\frac{S_{j,l}}{APT_S} \tag{9}$$

These equations represent the mechanism that as long as the orders remain in the system, they will eventually change priority. Since the flow of orders model does no longer keep track of individual orders and how much time they have left until their deadline, this phenomenon is abstracted by simply assuming that a small fraction of all orders within a given priority will change to a higher priority at each time step. How many depends on the amount of orders with the current priority P, the average time orders normally take to switch priority APT_P, and the time step dt. This also underscores the need to keep the amount of orders within the basins small, since large amounts of low-priority orders waiting in a section without getting processed will soon lead to a dangerous pile-up of high-priority orders.

2. **Movement of orders between sections**
In addition to describing the change of order priorities within sections, we must also formulate equations for the movement of orders between them. We define:
Outflow of each section:
Internal priority changes are not the only way orders of a particular priority will be diminuished, however - the outflow of the orders represent a vital part of the dynamics.

$$PS_{j,l}(O_{j,l}) = \frac{O_{j,l}}{AT_{j,l}}, \, if \, O_{j,l} \leq E_{j,l} \tag{10}$$

$$PS_{j,l}(O_{j,l}) = \frac{E_{j,l}}{AT_{j,l}}, \, if \, O_{j,l} > E_{j,l} \tag{11}$$

- $PS_{j,l}$: Processing speed of section $S_{j,l}$.
- $AT_{j,l}$: Average time required to process an order at section $S_{j,l}$.
- $O_{j,l}$: Number of orders at section $S_{j,l}$.
- $E_{j,l}$: Number of employees at section $S_{j,l}$.

The processing speed represents how fast any given section can process and pass on individual orders. As noted above, we do not aim to keep track of the precise status of individual orders and employees, as abstracts it into an averaged value. The processing speed of each section increases linearly with the amount of orders until it reaches a maximum value dependant on the number of employees at that section and the average time they require to process an individual order. This represents that the processing speed does not increase once there are more orders at a section than employees who can process them.

- $COut_{j,l}$: Outflow critical orders.

$$\frac{dCOut_{j,l}}{dt} = PS_{j,l}(C_{j,l}) \tag{12}$$

- $UOut_{j,l}$: Outflow of urgent orders.

$$\frac{dUOut_{j,l}}{dt} = PS_{j,l}(U_{j,l} + C_{j,l}) - \frac{dCOut_{j,l}}{dt} \tag{13}$$

- $StOut_{j,l}$: Outflow of standard orders.

$$\frac{dStOut_{j,l}}{dt} = PS_{j,l}(S_{j,l} + U_{j,l} + C_{j,l}) - \frac{dUOut_{j,l}}{dt} - \frac{dCOut_{j,l}}{dt} \tag{14}$$

Higher-priority orders are passed on to the next section before lower-priority orders. In the pipe model, this would mean that there are only a limited number of pipes leading to the basins in the following section. The liquid in the high-priority basins will flow through before the others. The equations capture this phenomenon. Each calculates the total processing speed for the sum of orders of the current and higher priorities, and then substracts the outflow of the higher priorities. If the higher priorities have already consumed the capacity in that section, the remaining outflow for the lower priorities will be zero.

Inflow of each section:

Likewise, the inflow from preceding sections influences the order dynamics at a station.

$$\frac{dCIn_{j,l}}{dt} = \sum_k (P(j-1,k,j,l)\frac{dCOut_{j-1,k}}{dt}) + \frac{dDO_{C,j,l}}{dt} \tag{15}$$

$$\frac{dUIn_{j,l}}{dt} = \sum_k (P(j-1,k,j,l)\frac{dUOut_{j-1,k}}{dt}) + \frac{dDO_{U,j,l}}{dt} \tag{16}$$

$$\frac{dStIn_{j,l}}{dt} = \sum_k (P(j-1,k,j,l)\frac{dStOut_{j-1,k}}{dt}) + \frac{dDO_{St,j,l}}{dt} \tag{17}$$

- $StIn_{j,l}$: Inflow of standard orders.
- $UIn_{j,l}$: Inflow of urgent orders.
- $CIn_{j,l}$: Inflow critical orders.
- $DO_{P,j,l}$: Inflow of direct orders of priority P from the customers into section $S_{j,l}$ (zero if the section has no direct connections to the customers).
- p(j-1,k,j,l): The probability that an order will be passed on from $S_{j-1,k}$ to $S_{j,l}$.

Now it is necessary to calculate the amount of orders that flow into any given section. This amount depends on the precise layout of the network of the individual sections, but in general, each section has one or more other sections that receive orders from it. If more than one new section accepts orders from the current section, the orders that flow from it must be split up.

When examining individual orders, there is a probability p for each of the following sections that it will end up at that section. Continuing our abstractions, the flow of orders from each section is split up, and the flow to each section is equal to the total flow multiplied by the probability p for that next section. The equations above total all the inflows (individual outflow times the probability for that individual section) over all preceding sections connected with the currently observed section.

Total change in each section:

$$\frac{dC_{j,i}}{dt} = \frac{dCIn_{j,i}}{dt} - \frac{dCOut_{j,i}}{dt} \tag{18}$$

$$\frac{dU_{j,i}}{dt} = \frac{dUIn_{j,i}}{dt} - \frac{dUOut_{j,i}}{dt} \tag{19}$$

$$\frac{dSt_{j,i}}{dt} = \frac{dStIn_{j,i}}{dt} - \frac{dStOut_{j,i}}{dt} \tag{20}$$

Note: The entry points for the orders can be defined in a similar way. They are simply inflows for the first sections in the work process chain. They can be either fixed, constant values representing a steady stream of new orders, or they can fluctuate to represent real-world cycles.

Advantages of the Simulation Model

Due to its high level of abstraction, the flow of orders model (in contrast to the cellular automaton-style algorithm model) is not able to track individual orders and their precise status. Because it 'averages' many parts of the work process, it also has difficulties with simulating the extremes of the work process, where random chance can lead to an individual section getting swamped by orders while having no work at all at other times.

The main advantage of this model, however, is simulating the long-term pressure on individual sections. Thus it should be able to accurately predict which sections will have more difficulties keeping up their capacity (depending on their number of employees, the average time they require to complete their part of the work process, and the amount of orders they receive from preceding sections) than others. This is an advantage over the by design a purely stochastic model, and thus requires many repeated simulations until it is possible to make statements about the coordination network (Schlick a. Killich, 2006) of work processes with any degree of confidence.

A further advantage is the scalability of the model. For the purpose of calculation time, it does not matter if a single section of the network describes a department with three employees working on 150 orders per day, or sixty employees working on 3,000 orders per day - within the model, the only part that changes are model constants that do not affect calculation time.

In stochastic models, on the other hand, a similar increase will both drastically increase the calculation time for a single program run, as well as the number of program iterations required to generate statistically significant results.

In the following chapter, we use this PDE model concept to analyse the dynamic behaviour of inter- and intra-branch office teamwork including their organisational interfaces (Brockhoff, 1994; Brockhoff a. Hauschildt, 1993; Fischer, 1993; Feierabend, 1987). The simulator (see Fig. 5) describes clearly the behaviour of the process chain (see Fig. 1). For a more detailed understanding with regard of our results, we define the following three states (Ijioui et al., 2006b, pp. 70-73) (see Fig. 6), which help us to evaluate the described process chain:

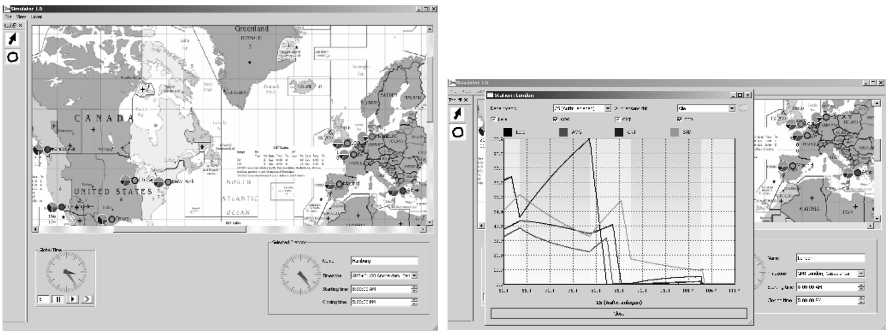


Fig. 5. Graphical user interface of the simulator.

- **Operating process chain (PC_{Opera})**: process state adding excellent value due to a stable circulation of orders.

- **Metastable process chain** (PC_{Meta}): process state adding moderate value due to a regular circulation of orders which is nevertheless vulnerable to extreme events.
- **Collapsed process chain** (PC_{Collap}): process state adding little value due to a breakdown in the regular circulation of orders.

These criteria were defined to help understand the simulation results.

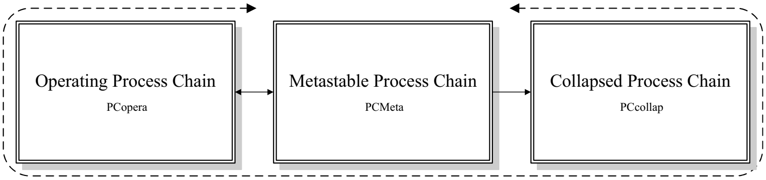


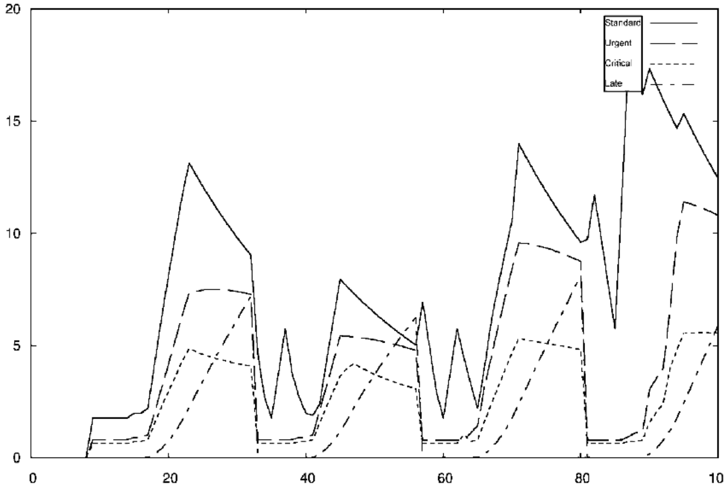
Fig. 6. Possible transitions of states of the process chain. Note that there is no return to a metastable state possible once the process chain has collapsed.

Results of the Simulation

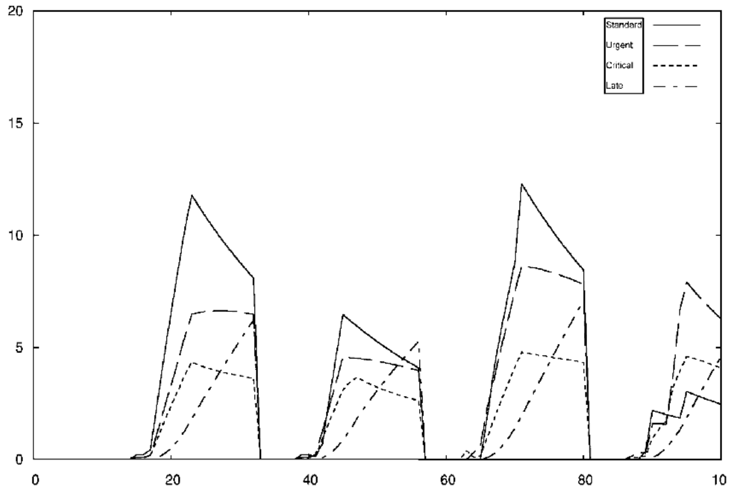
The following figures reveal our simulation results for the current cooperating process chain. We see that the critical orders (C) are accomplished and passed on and worked on in preference of all others, leaving out parts of individual phases as sketched for example in Figure 7. While this assures that these orders are completed in time in most cases, it generates a large bottleneck of standard (St) orders which are eventually upgraded to urgent (U) or even time critical (C) ones while they wait for being assigned to employees[9].

After 5 p.m. German time we record a very strong increase in the order volume that is mainly caused by the Texan order influx (see Fig. 7 (a)). Only after 11 p.m. German time does this order influx stop. After this point both stations are inactive which explains the consistent 9-hour course of events during this period. We also found that the time-zone factor leads to extraordinarily high idle periods for orders. Orders arriving after 5 p.m. German time are not processed before 8 a.m. on the following day. The process chain is in a PC_{Collap} (collapsed state) as defined above. The same also applies to the

[9] In the future, increased demand from airlines thanks to increased air traffic means that airlines might no longer be able to tolerate standard orders (St), leaving a mixture of critical (C) and urgent (U) orders. To keep up with the increased demand, supply companies will have to reexamine their process chain and optimise it to provide the same high-quality service their customers are used to while at the same time keeping up with the larger number of high-priority orders (see also Schneider, 2007).



(a)



(b)

Fig. 7. Total number of orders (Germany/Texas). The axis of abscissae (x) represents the hours since of start of the simulation, and the axis of ordinates (y) represents the number of orders currently within the section. Higher priority orders will be worked on first, leading to an acuumulation of lower - priority orders in time, giving rise to late orders (see figure (a)). Allotted share from Texas (orders sent to Germany from Texas for completion) (see figure (b)).

Chinese order influx. In this case third party orders accumulate between midnight and 8 a.m. (see Fig. 9 (a)). This means that between 8 a.m. and midday German employees must use the majority of their resources to process the

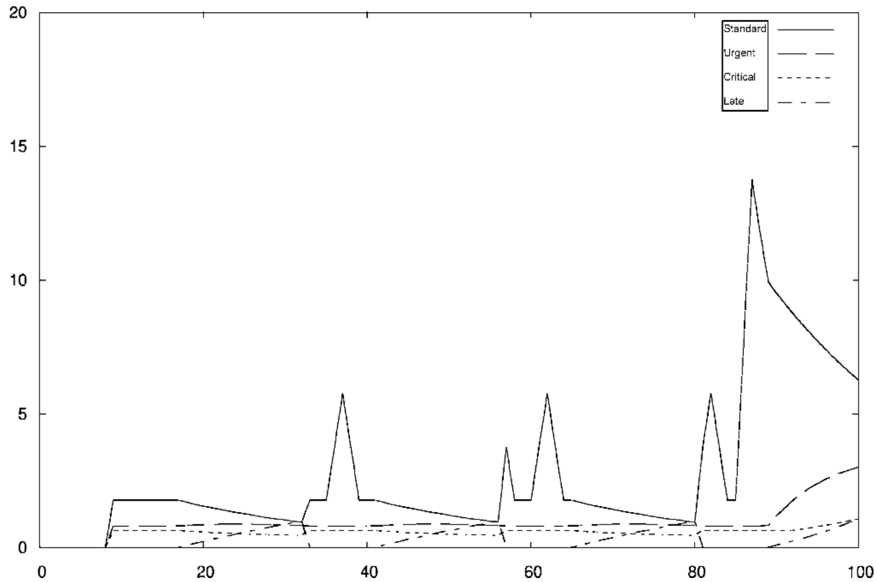


Fig. 8. The same as Figure 7 (a), but without order inflow from Texas. The process chain is in a $ProcessChain_{Opera}$ (operating state) as defined above.

orders that have accumulated. Our process acceptance and our simulation enabled us to confirm this process. For our illustrative purpose we have filtered the orders arriving from Texas (see Fig. 7 (b)) which are due to be processed in the German station (see Fig. 7 (a)).

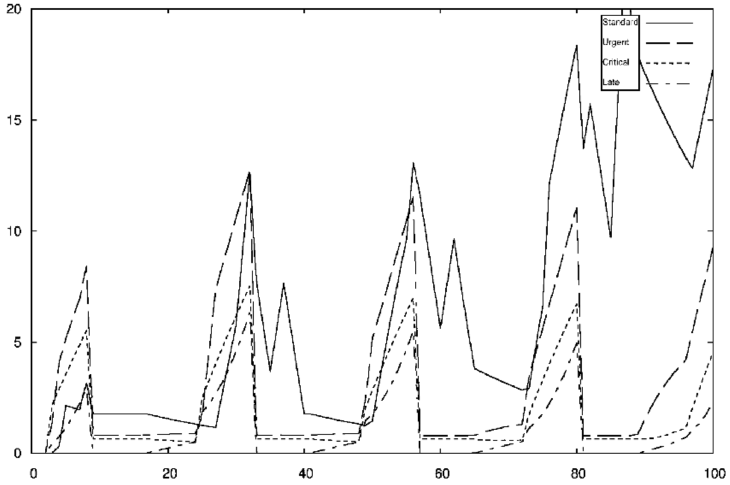
Figure 8 illustrates the reduction of the strain on the German station regarding the Texan order influx.

We can transfer the result of the case study to all branches that have a similar time-zone difference in relation to the parent station. For the present process chain these are Texas (GMT-06:00), China (GMT+08:00), Singapore (GMT+08:00), Australia (GMT+10:00), etc. (cf. Müller, 2005). Stations that operate in the same time zone as the parent station do not suffer from the long idle period mentioned above (see Fig. 9 (b)).

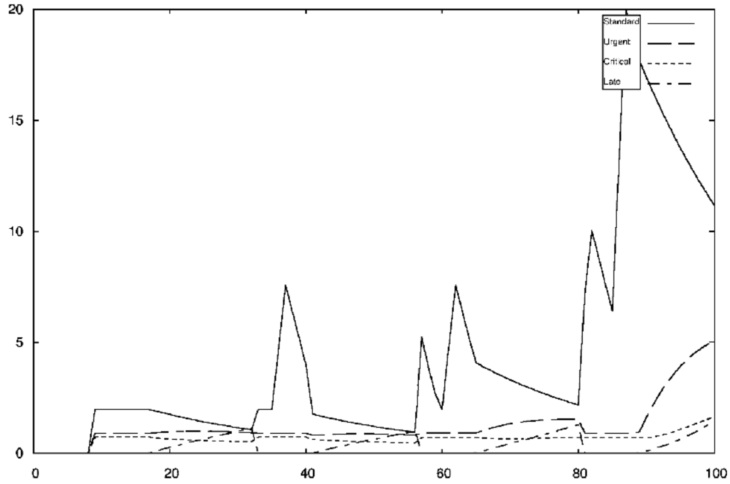
These simulation results clearly revealed the weaknesses in the as-is global interfaces and confirmed the suspicions of senior management that action was needed.

Findings of the Weak-Point Analysis

Here in this chapter we at last show the discovered weaknesses which as described earlier were discovered both manually and via simulations. The resulting requirements for the target process are then listed in the chapter 'De-



(a)



(b)

Fig. 9. (a) Total work (Germany/China). Roughly the same problem as Figure 7 (a). Ultimately, this leads to an inability to complete all orders in time, giving rise to late orders. (b) Order inflow from a station within the same time zone (here from France). As can be seen, there are no unnecessary wait periods from out-of-time zone orders. This process chain is in a $ProcessChain_{Meta}$ (metastable state).

rived Design Requirements'. The non-value added proportion of the cycle time shown can be explained by examining numerous contributions to it. In our approach the reference model by Haage (2003, pp. 111-292; q.v. Göpfert a. Haage, 2004) was used as the work basis. As a hypothesis, the author identified 111 time consumers for analysing the business processes. Of these time consumers we were able to confirm the following consumers for the process chain described above:

1. The interfaces between the branch offices were extremely inefficient (see the simulations).
2. The internal interfaces were also inefficient, though for different reasons. Communication between sections was organised via "In" trays and "Out" trays, and the speed at which they were emptied out and transported dominated the overall speed of the process (see e.g. Fig.2 or Fig. 3).
3. Because of inefficient structure in organizing time-critical orders, the employees had difficulties setting the right priorities when it came to processing them.
4. The movement of orders and information was not fully observable (i.e. low level of transparency).
5. The information needed for completing the processes were not organised efficiently - they were communicated either by paper or verbally.
6. The latest advances in telematics had not yet been fully implemented.
7. The process chain was organised via so-called "tracking lists" which kept track of specific daily, weekly or monthly milestones, such as (q.v. Hägele, 2005; Ijioui et al., 2004):
   - The order tracking list shows the order statuses to be monitored. The aim is to activate inactive work steps on time.
   - The stock list manages the orders in relation to stocks. The employee uses the stock list to check the current status of these orders with regard to further processing.
   - The order tracking list for orders without reservation manages orders for which no reservation has been made yet.
   - The tracking list for the received postponed goods supports employees in identifying possible delays in advance (if there is a variance the customer must be notified as soon as possible).
   - The overdue list documents the deliveries expected during the week (despite the name, the list does not only list orders which are already late, but all which have the *potential* to be late during the week).
   - The order confirmation list provides the employee with an overview of the order confirmations by the supplier that are missing or have not been received yet.
   - The blocked warehouse list contains an overview of incomplete deliveries.
   - The clarification list indicates to the employee the issues that need to be clarified.
   - The late stock list indicates to the order processing employee the current goods which have arrived in the warehouse and thus can have delivery papers prepared for them.

Derived Design Requirements

It took about 24 months to determine the requirements which were recorded based on individual interviews as well as in numerous workshops (cf. also Ijioui et al., 2004/2006a; Müller, 2005). From these requirements, we were able to develop the concept for the improved process chain. We then accompanied the implementation of the concept to keep them informed. The integration of the employees was a vital necessity for ensuring the success of the project (see e.g. Hill et al., 1992), as otherwise our suggestions would have face rejection as soon as they had been offered (Bretzke, 2005; Engelmann, 1995; Becker a. Schmidt, 2005; Hill et al., 1992). With their cooperation, we were able to complete the first phase of the validation process for the innovations. To summarise, the most significant results of the meetings can be isolated as follows:

What is required is a system design

1. that will in the future release the employee from carrying out any control activities.
2. that centralises the essential information data (cf. Mesenhöller, 2003, p.6 et seq.). The information must be free of gaps, up-to-date and available more or less instantaneously (see the classification by Binner, 2004, p. 456).
3. that provides the employees at any time with the opportunity to track their orders throughout the entire process chain (transparency).
4. that permits the company to control its individual steps and monitor the quality of its solution in a system-based manner so that every employee experiences a noticeable drop in the workload in the area of 'Exception Management' (see, for example, Bretzke, 2002, pp. 27-31; Ijioui et al. 2006a, pp. 41-46).
5. that ensures personalised assignment of tasks to be completed (see, for example, Oberweis, 1996b, p. 83).
6. that relieves the employee from time-consuming manual sorting. At present every employee must continuously check the inbox for the correctness of the processing sequence when collecting an order. This work step has been identified as a resource-binding activity.
7. that manages all delivery dates - currently, the majority of all deadlines are monitored and controlled manually. This routine activity has also been identified as highly resource-binding. The system should
   - ensure a clear representation of all deadlines.
   - identify deadlines that are difficult to keep early on and notify the employees responsible, providing information if there are delays.
8. that makes it possible to integrate all partners and connected systems (customers, suppliers, etc.).
9. that is used at the operational level as well as at the management level.
10. that tells the employee which tasks must be completed first.

11. that ensures automatic forwarding to a pre-defined substitute if an employee is not available.
12. that defines at what time which activities of the individual employee must take place.
13. that renders the entire process chain visible (from the supplier to the customer).
14. that ensures mobile information provision (e.g. by means of SMS, e-mail, etc.).
15. that reduces or even eliminates all unnecessary movements.

Due to these requirements the guiding design principles of Supply Chain Event Management (SCEM) (Bittner, 2000; Bretzke 2002; Busch et al., 2003; Frost & Sullivan, 2003a; Klaus, 2004; Knickle, 2001; Kruppke, 2005; Mors, 2002; Negretto, 2002; Nissen, 2002; Paschke a. Zimmermann, 2003; Schieg et al., 2002; Steven a. Krüger, 2004; Zimmermann, 2006) and the advantages of pneumatic delivery systems (Mäussnest, 1971) were recognised as significant (Ijioui et al., 2007a/2007b) for this project and are able to automate most of the listed requirements.

First we will examine the SCEM component of our solution. For a better understanding we will start by listing a few selected definitions in terms of SCEM below. For Stork (2002, pp. 57-60) SCEM is

> ”*...software-related monitoring, proactive notification, decision finding and the control of processes..., that must be controlled within a company as well as across companies*”.[10]

Steven and Krüger (2004, p. 194) see SCEM as

> ”*...a concept for proactive and short-term planning, management and control of logistics processes along the global supply chains*”.[11]

Nissen (2002, pp. 477-480) defines SCEM as

> ”*...a concept that is used to capture, monitor and evaluate events within a company and between companies*”.[12]

According to AMR Research (2007) the SCEM

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[10] Original: ”...softwaremässige Überwachung, die proaktive Benachrichtigung, die Entscheidungsfindung und die Kontrolle von Prozessen ..., die sowohl innerhalb eines Unternehmens als auch Unternehmensübergreifend gesteuert werden müssen”.

[11] Original: ”...ein Konzept zur proaktiven und kurzfristigen Planung, Steuerung und Kontrolle von Logistikprozessen entlang der globaler Supply Chains.”

[12] Original: ”...ein Konzept, mit dem Ereignisse innerhalb eines Unternehmens und zwischen Unternehmen, erfasst, überwacht und bewertet werden.”

> "*...processes and systems alert companies to any unplanned changes in supply lines or other events so they can respond with alternatives. The set of integrated functionality crosses the five business processes of* ***Monitor****,* ***Notify****,* ***Simulate****,* ***Control****, and* ***Measure*** *supply chain activities.*"

This approach is a fairly recent development (cf. also Teuteberg, 2007, pp. 15-35), but in the near future companies will have to implement it, as they will no longer be able to afford maintaining business processes which are not completely transparent. Therefore I am personally convinced that globally operating companies will only be able to meet the challenges of globalisation with the aid of SCEM. This claim is supported by (Bittner, 2000; Bretzke, 2002; Busch et al., 2003; Frost & Sullivan, 2003a; Klaus, 2004; Knickle, 2001; Kruppke, 2005; Mors, 2002; Negretto, 2002; Nissen, 2002; Schieg et al., 2002; Steven a. Krüger 2004; Diessner, 2007, pp. 71-83; Heusler et al., 2006), who also confirm the functions mentioned in the definitions (see also Fig. 10).

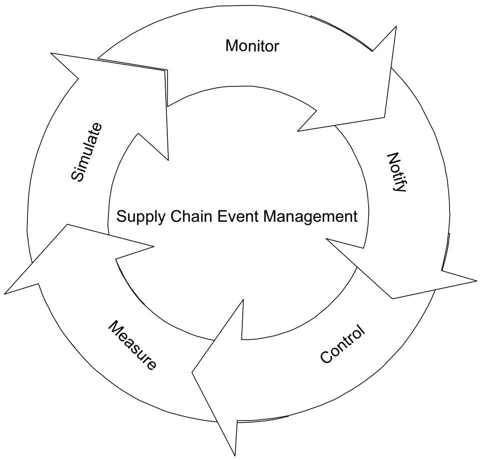

Fig. 10. This figure illustrates the intended basic functions of the SCEM system.

When consulting Becker (2007, p. 57), the management level, in particular, experiences a significant drop in the workload in the area of 'Exception Management' (see also Bretzke, 2002, pp. 27-31; Ijioui et al., 2006a). Küppers and Ewers, distinguished experts in the pharmaceutical industry, confirm the benefit and point out that the introduction of the SCEM in the pharmaceuticals-oriented supply chain "*is only a matter of time*" (Küppers a. Ewers, 2007, pp. 37-55; q.v. for further information Küppers, 2006, pp. 393-399).

A similar expectation has been voiced by Hagen (2007; q.v. the interview section of this book) - Manager of T-Systems Business Services (business customer segment of Deutsche Telekom AG) when he was questioned by the author on the positive effects he expected from the SCEM-System:

Hagen: *Such a concept would bring a new dimension of transparency and control possibility. Remarkably here that this would not only lead to immediate internal improvements - e.g. elimination of entropy and possibilities for automation - but also generates respective similar external effects. We would expect precisely a more positive customer perception, a cost reduction and the possibility to co-operate more effectively with suppliers and customers - keyword B2B (Business-To-Business) integration. In the logistics industry this has been recognised for a long time already and we also think very intensely about how we can develop, construct and implement such a process-monitoring- and event-management-system effectively and efficiently.*

As far as market acceptance is concerned, Teuteberg's study offers an informative insight (Teuteberg, 2007, pp. 15-35 and http://mib.uni-ffo.de). We learn from this study that currently only 10% of the 60 companies surveyed intend to introduce or consider introducing SCEM (see Fig. 11). Similar results are also indicated by the market rsearch institute AMR Research (cf. Knickle, 2002/2001 (cited by Nissen, 2002)).

Features		Percent
Companies	Automotive industry	6,70%
	Consulting	3,30%
	Chemical industry	3,30%
	Electro-technics	6,70%
	Wholesale and retail	8,30%
	Timber and paper industry	8,30%
	IT	5,00%
	Logistics services	8,30%
	Mechanical engineering	10,00%
	Metal industry	16,70%
	Pharmaceutical industry	3,30%
	Textile industry	5,00%
	Transport, logistic and traffic	13,30%
	others	1,70%
Number of employees	less than 100	32,80%
	100 - 1.000	19,70%
	1 001 - 10 000	18,00%
	10 001 - 100 000	18,00%
	more than 100 000	11,50%
Volume of sales	less than € 10 Mio.	21,30%
	€ 10 Mio. - € 100 Mio.	31,10%
	more than € 100 Mio. - € 1 Mrd.	16,40%
	more than € 1 Mrd.	31,10%

Fig. 11. The distribution (cf. Teuteberg, 2007)

Personally I support the statements made by Nissen who has explained that most of these functions already exist in other form (Bartsch a. Bickenbach, 2001 (cited by Nissen, 2002, pp. 478)), but that the current main goal of the market is to implement monitoring and notifying in order to realise a complete SCEM system (cf. Nissen, 2002, pp. 478).

I wish to add that the Interchain concept described in the next chapter is based on SCEM, and thus also supports resource management in addition to monitoring and notifying.

Conceptualised Organisation

As mentioned before, the new management architecture[13] developed in this project is called 'Interchain' (see Fig. 12). 'Interchain' combines the company name (which in turn derived from the **inter**national nature of its operation (Duden, 2007)) with a basic component of logistics - the business process **chain**.

The linchpin of the design is the 'Interchain' system, which is a web and rules-based software approach that allows us - based on systems - to monitor the individual process steps introduced in chapter 'The Initial Business Process of Interturbine Logistik' as well as to control the quality of the solution (Siebert, 2006, p. 47, Ijioui et al. 2006a).

Based on the rule mechanisms stored (business rules) (see for example also Klaus, 2004; Wieser a. Lauterbach, 2001), 'Interchain' records, monitors and analyses the data transferred by the Enterprise Resource Planning (ERP) System4 and triggers a targeted notification to be sent in the event of a rule violation. In general, the ERP System4 can be viewed as the knowledge database of the 'Interchain' system.

Every variance identified (see e.g. Fig. 6 by Diessner a. Rosemann q.v. Heusler et al., 2006) will be made available to the employee responsible visually in his GUI (Graphical User Interface) for clarification and clearance (Steven a. Krüger 2004, pp. 184-185). In addition, every employee (see organisational chart) is told by the system:

> "*...what everyone has to do how in what situation, who... has to obey whom, who needs to be notified of what and by whom...*"[14] (Ellwein, 1990, pp. 165).

Timely interaction between both systems as required since the overall process is made possible by a communication interface specifically developed for the project (cf. Siebert, 2006 for further general information see also Comer, 2000, p. 474; Mors, 2002, p. 27) which ensures, for example,

[13] In developing the architecture we were also inspired by the ARIS model developed by Scheer (Scheer a. Jost, 2002; Scheer, 1992/1997; Jost a. Wagner, 2005)

[14] "...was jeder in welcher Situation auf welche weise zu tun hat, wer wem ... zu gehorchen hat, wer über was und durch wen zu informieren ist..."

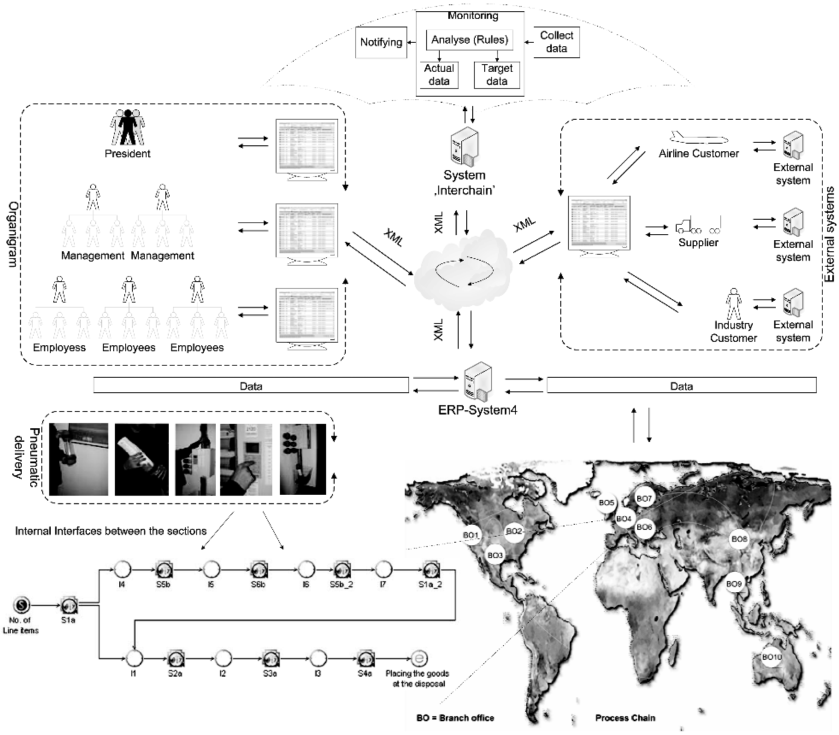

Fig. 12. Organisational concept: The network on the lower left side shows the as-is situation in Germany. The internal network interfaces were solved with a pneumatic delivery system (upper left side). The technical realisation of the Interchain system is shown on the upper right side: The umbrella at the top represents the computerised Interchain system in Bremen receiving the raw data from the Enterprise Resource Planning (ERP) system integrated into Interturbine in Kaltenkirchen, which gathers all process data. On the left we see the personalised GUIs for each level of employee or manager within the company. In the future, further integration with outside systems is planned, as shown on the right side.

- bi-directional data transfer,
- timely data transmission, as well as
- secure data transformation.

The implementation of the concept uses the XML language as the transmission format. A good overview over the advantages of XML and the disadvantages of other languages for this specific purpose can be found in (Kraft, 2007; Anderson et. al., 2000):

- It is a standardised language.
- The language is simple and easy to learn.

- It is user-friendly and structured.
- Its logic is easy to understand.

An informative insight into the 'Interchain' system is provided by the following selected material management frontend views (all departments have a similar user interface - apart from a few exceptions). We refrain from explaining every detail and focus only on the components that are important in relation to the process chain.

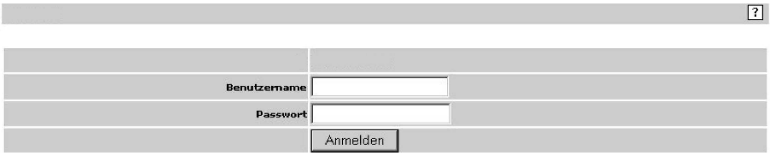

Fig. 13. This figure illustrates the login.

The starting point of the Interchain system is the login process where the employee enters his user name and the corresponding password (see Fig. 13). Once he has logged in successfully, the employee is given a GUI specifically tailored to him (see Fig. 14) (see also SAP, 2001; Wieser a. Lauterbach, 2001).

The employee is directed by the system to the most urgent tasks in order to utilize his available time to the best effect (see also Oberweis, 1996b, p. 69 et seq.). A set of rules ensures timely processing, monitors the measuring points implemented and - based on a traffic light function - notifies the employee of the processing urgency if an interval has been exceeded:

- An order with a green status colour signals to the employee that no action is currently required.
- An amber status shows the employee that he is expected to act during office hours.
- A red status - also to be understood as a warning colour - signals to the employee that the order is overdue and must be processed most urgently.

In addition, the employee is only shown the information that is necessary for the handling process (see main mask). For procurement, the following information - in addition to the order status - has been identified as critical:

- the purchase order number,
- the priority of the order (AOG, CRT, EXP, STD),
- the supplier name / location,
- the order date and the dispatch date,
- the internal order number.

This is meant to ensure manageability. Furthermore, the filter functions make it possible to filter orders by specific attributes which we believe will

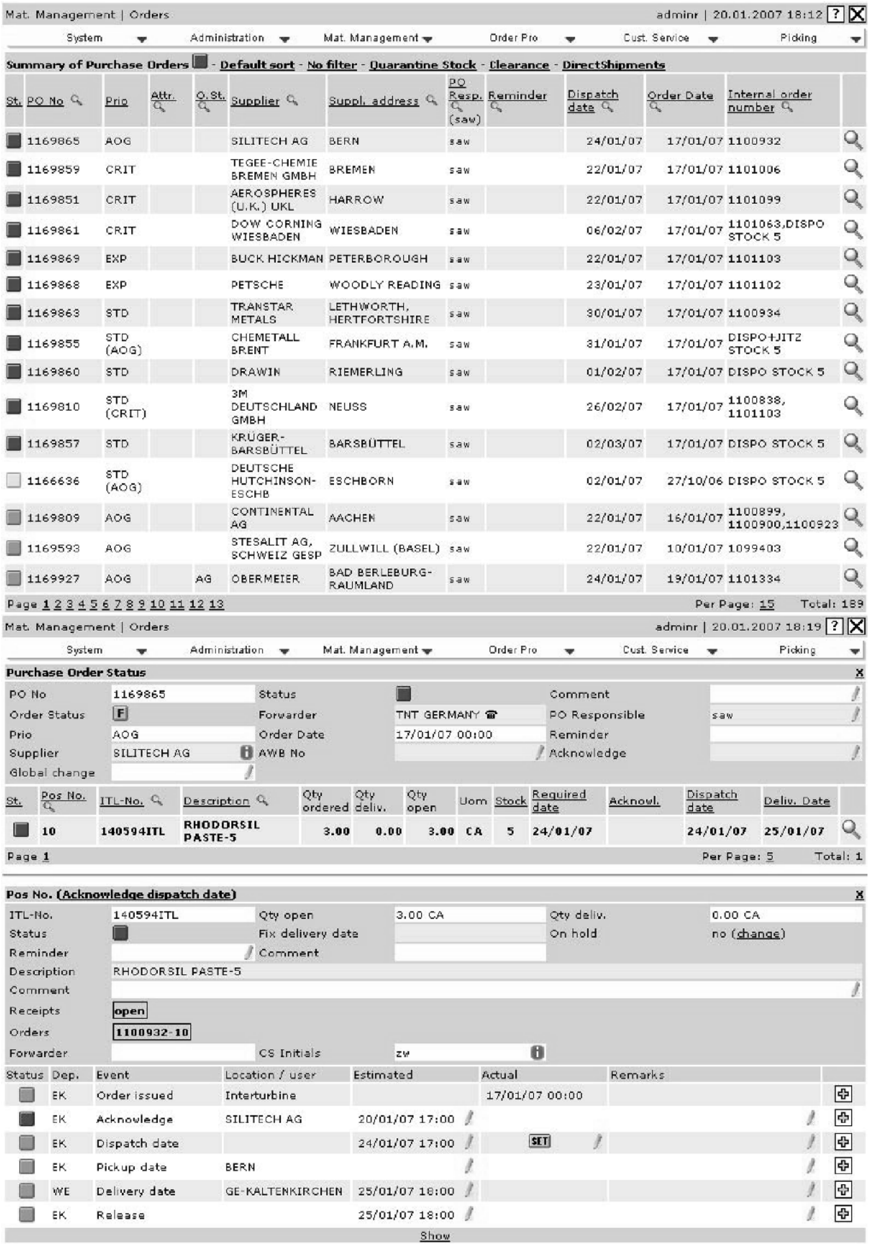

Fig. 14. The individual front-end of the material management employee.

improve the process of finding information. If the employee requires in-depth information data for a specific order, he can call up these details via the magnifier (see Fig. 14: far right). In the sub-mask the employee will find, amongst other things,

- detailed contact data for the supplier (see the blue information button).
- the telephone number of the forwarder.
- a classified sorting of the order items (note: an order normally comprises several items).
- a comment field allowing additional general information to be entered (for the working groups involved).

Before the implementation of this system, none of this information was organised efficiently, leading to enormous time losses. The 'Interchain' system also provides a schedule for controlling and monitoring the process chain illustrated.

- The 'Department' column lists the embedded departments.
- The 'Event' column specifies a department's most important key events that are to be monitored by the system.
- The 'Location' column shows all companies (apart from a few exceptions) that are relevant for the manufacture and provision of the product.
- The 'Estimated' and 'Actual' columns illustrate to the employee whether the time interval allocated to executing the sub-process has actually been adhered to.
- The 'Remarks' column can be used to enter additional information not sufficient conveyed by the other categories in case of unique events.

We would like to point out that this is not just an operational system. With regard to routine activities, the 'Interchain' system also offers efficient help at strategic management level. With 'Interchain' the manager has the option

- to efficiently analyse the actual utilisation of individual employees by means of filter functions (in order to initiate a measure in good time in the event of an emergency).
- to obtain information on the current state of processing of the individual orders at any time.
- to get involved in the ongoing process at any time.
- to redistribute his globally available employee resources at any time or to take corrective control measures (for example, it an employee is stressed as a result of too many 'red' orders while others only deal with 'green' or 'amber' orders.).

The manager is able to monitor individual employees via their initials with special filter functions, as shown in the 'Initials' column (Fig. 14 see upper level). As the image shows, the manager observes the employee 'saw' who currently is working on 11 red ('highly critical), 1 yellow ('urgent'), and 3 green ('non-urgent') orders in the current. With this information he is able to evaluate the available time resources of his employee (for example, by shifting red orders to employees who do not currently have one - something which was impossible before the implementation of the system). By clicking on one of the magnifying glasses at the end of a row, he can gain more detailed information about a specific order (see Fig. 14 at middle level).

Lower level shows the schedule of an individual order, highlighting possible problem areas within the network of work section/stations. The red signs represent process steps which have not yet been completed. The 'Event' column lists the individual process steps which have to be completed for the order to finish. The 'Estimated' column shows the planned time of completion for a particular process step, while the 'Actual' column lists the time when the process step was actually completed.

Note: This is precisely the level of transparency and control which I set out to implement in the course of this project, as neither of these was possible before the start of the project.

Apart from point (15) (see chapter 'Derived Design Requirements') all requirements listed could be fulfilled with this system. As far as the unnecessary movements are concerned (point 15), we pointed out in e.g. chapter 'Findings of the Weak-Point Analysis' that this is a resource-binding and time-consuming activity. The following diagram illustrates the routes (see e.g the arrows in Fig. 2 and Fig. 3) and summarises the inefficiency of these unnecessary movements as determined in the project (see Fig. 15).

	Bidirectional	Interation/per section	Net time	Additional time/per section	Total time
S1a (first floor) - S5b	406 m				
S1a (second floor) - S5b	440 m	8	58,67 min.		90,67 min.
S5b - S6b	368 m	8	49,07 min.		81,07 min.
S1a (first floor) - S2a	214 m			4 min.	
S3a (first floor) - S4a	77 m	8	28,53 min.		60,53 min.
S1a (second floor) - S2a	248 m				
S3a (second floor) - S4a	94 m	8	33,07 min.		65,07 min.

Fig. 15. As we can see from the table the transport routes (approx. 10 Km/day - see Fig.3) alone bind 5 h/day in human ressources when added up over all employees (Source: Interturbine Logistik GmbH - cf. also Hägele, 2005, Ijioui et al., 2004 (company-internal document)).

Since the documents of the process had to be physically transferred (as originals) from one responsible person to another, it was not possible to convert the documents into electronic form (Arnold, 2000, p. 7). Due to this problem we had to specially design a solution for this manual process which eliminates these transport routes and also ensures a transfer performance of almost 100%. In respect of this challenge, the established pneumatic tube technology turned out to be the most suitable transport system.

Despite today's highly developed communication and information technology, this pneumatic transport procedure has always been an economic, efficient, low-maintenance and reliable transport system (Mäussnest, 1971, p. 1). Looking at the following publication (Arnold, 2000 citing Rohrpostanlagen, 1959, p. 5), pneumatic dispatch offers the following usage potential, amongst other things. The technology

- has a positive effect on staff capacity as all manual transport routes are removed.
- increases transport speed approximately 10-fold. Mäussnest points out that the capsule speed could be as high as 150 km/h (Mäussnest, 1971, p. 1).
- is many times more economic than having an employee hand over the documents manually.
- enables a smooth process flow without interruptions.
- ensures - unlike e-mails - secure, secret and reliable transfer of documents between the units.

Figure 16 (lower side) illustrates the newly designed transport process to stop unnecessary movements. The sequence of the sending process (see upper side) can be described as follows:

(a) A transport capsule weighing 0.5 kg is used for transport.
(b) The employee inserts the documents into the capsule.
(c) The capsule is then inserted into the pneumatic tube station.
(d) Following this, the employee dials the number of the desired destination.
(e) The diagram demonstrates the arrival of the capsule.

Regarding the global interfaces we were able to identify the time zone problem as the single greatest cause of efficiency loss by far on the basis of our simulations (see chapter 'Results of the Simulation'). As the third improvement concept we suggested alleviating this problem through partial autonomy of the identified stations (it is Intention that all branch offices with sufficiently large stock and if they can supply from stock can process local orders autonomously (e.g. Texas from Texas, France from France etc.)) (see Müller, 2005).

Validation: Valuation of Suitability

Interchain Management System

The test phase for the Interchain system lasted for approximately one year. The initial schooling and test phase was executed by us in person at the site with selected participants - the core team. Afterwards the trained core team was responsible for the further process in the company. To avoid endangering

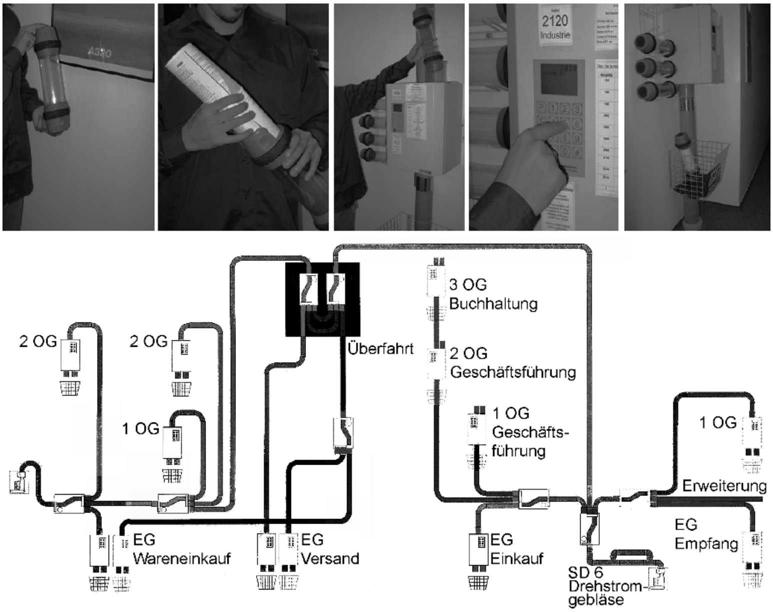

Fig. 16. (a) Procedure. (b) The new pneumatic delivery based interaction (cf. Arlt, 2006).

the process chain, we initially introduced the Interchain system in the material management in January 2007. This department was especially qualified for testing purpose since unlike the others its work requirements remained at a relatively stable level throughout, allowing for comparisons of the work efficiency before and after the changes. A first general survey indicated that the use potential (Nissen, 2002, pp. 479-480) of the system resulted in noticeable improvements especially in the informational based work sector (e.g. Mesenhöller, 2003, p. 6 et seq.). We expect similar potential from the introduction of the system in the other individual departments. A further improvement can be expected after the implementation of the entire process chain into the Interchain system (branch offices, customer, and suppliers).

Pneumatic Delivery System

The best currently available measurements were attained thanks to the introduction of a pneumatic delivery system, with which the local interfaces (within a single station) were connected more efficiently. It was possible to reduce the resource-wasting and unnecessary movements of 5 h/day as shown in Figure 15 to few minutes respectively seconds. An impressive example of the efficiency gain attained by using pneumatic delivery system can be seen in Figure 17. The pneumatic delivery system removed unproductive breaks (Mäussnest, 1971, p. 1; Arnold, 2000 citing Rohrpostanlagen, 1959, p. 5) within the flow of orders by preventing lengthy wait periods before orders could be transported to a new section. The newly available work time was reinvested into processing a greater amount of orders within the same time period. The senior management estimates that thank to this system the company was able to save approx. 1.3 employees in the first six months alone. Moreover, we have demonstrated that it is not always necessary to implement the latest technological advances, as this can easily lead to expensive over-engineering.

StartTime	EndTime	TotalTime	SendTime
08.01.2007 08:13:46	08.01.2007 08:14:34	00:00:48	00:00:48
08.01.2007 08:16:43	08.01.2007 08:17:29	00:00:46	00:00:46
08.01.2007 08:17:55	08.01.2007 08:18:45	00:00:50	00:00:50
08.01.2007 08:20:38	08.01.2007 08:21:27	00:00:49	00:00:49
08.01.2007 08:27:53	08.01.2007 08:28:41	00:00:48	00:00:48
08.01.2007 08:28:41	08.01.2007 08:29:32	00:01:09	00:00:51
08.01.2007 08:29:45	08.01.2007 08:30:27	00:00:42	00:00:42
08.01.2007 08:30:29	08.01.2007 08:31:13	00:01:21	00:00:44
08.01.2007 08:31:40	08.01.2007 08:32:21	00:00:41	00:00:41
08.01.2007 08:32:23	08.01.2007 08:33:05	00:01:19	00:00:42
08.01.2007 08:33:08	08.01.2007 08:33:59	00:01:37	00:00:51
08.01.2007 08:33:59	08.01.2007 08:34:41	00:00:49	00:00:42
08.01.2007 08:34:43	08.01.2007 08:35:25	00:01:20	00:00:42
08.01.2007 08:36:42	08.01.2007 08:37:25	00:00:43	00:00:43
08.01.2007 08:37:27	08.01.2007 08:38:12	00:01:18	00:00:45
08.01.2007 08:38:13	08.01.2007 08:39:03	00:01:35	00:00:50
08.01.2007 08:39:03	08.01.2007 08:39:53	00:01:06	00:00:50
08.01.2007 08:39:53	08.01.2007 08:40:43	00:01:31	00:00:50
08.01.2007 08:40:43	08.01.2007 08:41:30	00:01:31	00:00:47
08.01.2007 08:41:30	08.01.2007 08:42:15	00:01:02	00:00:45
08.01.2007 08:42:55	08.01.2007 08:43:41	00:00:46	00:00:46
08.01.2007 08:43:42	08.01.2007 08:44:28	00:01:29	00:00:46
08.01.2007 08:46:30	08.01.2007 08:47:18	00:00:48	00:00:48
08.01.2007 08:49:34	08.01.2007 08:50:16	00:00:42	00:00:42
08.01.2007 08:50:19	08.01.2007 08:51:07	00:00:58	00:00:48
08.01.2007 08:51:07	08.01.2007 08:52:35	00:01:53	00:01:28
08.01.2007 08:51:47	08.01.2007 08:52:42	00:02:04	00:00:55
08.01.2007 08:53:17	08.01.2007 08:54:09	00:00:52	00:00:52
08.01.2007 09:00:32	08.01.2007 09:01:18	00:00:46	00:00:46
08.01.2007 09:01:24	08.01.2007 09:02:06	00:00:42	00:00:42
08.01.2007 09:02:44	08.01.2007 09:03:26	00:01:55	00:00:42
08.01.2007 09:03:29	08.01.2007 09:04:17	00:01:39	00:00:48
08.01.2007 09:09:47	08.01.2007 09:10:29	00:00:42	00:00:42
08.01.2007 09:10:31	08.01.2007 09:11:17	00:01:15	00:00:46
08.01.2007 09:11:18	08.01.2007 09:12:01	00:01:23	00:00:43
08.01.2007 09:12:04	08.01.2007 09:12:53	00:02:36	00:00:49
08.01.2007 09:12:53	08.01.2007 09:13:44	00:02:32	00:00:51
08.01.2007 09:13:44	08.01.2007 09:15:00	00:01:16	00:01:16
08.01.2007 09:14:15	08.01.2007 09:14:58	00:01:06	00:00:43
08.01.2007 09:18:07	08.01.2007 09:18:58	00:00:51	00:00:51
08.01.2007 09:23:37	08.01.2007 09:24:26	00:00:49	00:00:49
08.01.2007 09:25:16	08.01.2007 09:25:59	00:00:43	00:00:43
08.01.2007 09:27:10	08.01.2007 09:28:00	00:00:50	00:00:50
08.01.2007 09:28:04	08.01.2007 09:28:47	00:00:43	00:00:43
08.01.2007 09:28:49	08.01.2007 09:29:35	00:01:20	00:00:46
08.01.2007 09:41:41	08.01.2007 09:42:31	00:00:50	00:00:50
08.01.2007 09:42:33	08.01.2007 09:43:16	00:01:19	00:00:43
08.01.2007 09:43:17	08.01.2007 09:44:00	00:01:19	00:00:43
08.01.2007 09:44:03	08.01.2007 09:44:49	00:02:27	00:00:46
08.01.2007 09:51:18	08.01.2007 09:52:09	00:00:51	00:00:51

StartTime	EndTime	TotalTime	SendTime
08.01.2007 09:52:36	08.01.2007 09:53:25	00:00:49	00:00:49
08.01.2007 09:59:11	08.01.2007 10:00:04	00:00:53	00:00:53
08.01.2007 10:00:04	08.01.2007 10:00:51	00:00:49	00:00:47
08.01.2007 10:01:29	08.01.2007 10:02:17	00:00:48	00:00:48
08.01.2007 10:04:00	08.01.2007 10:04:42	00:00:42	00:00:42
08.01.2007 10:04:45	08.01.2007 10:05:27	00:01:23	00:00:42
08.01.2007 10:05:30	08.01.2007 10:06:15	00:01:24	00:00:45
08.01.2007 10:06:17	08.01.2007 10:07:03	00:01:01	00:00:46
08.01.2007 10:07:05	08.01.2007 10:07:54	00:03:29	00:00:49
08.01.2007 10:13:22	08.01.2007 10:14:12	00:00:50	00:00:50
08.01.2007 10:14:12	08.01.2007 10:15:03	00:01:14	00:00:51
08.01.2007 10:18:30	08.01.2007 10:19:17	00:00:47	00:00:47
08.01.2007 10:19:19	08.01.2007 10:20:37	00:01:41	00:01:18
08.01.2007 10:22:59	08.01.2007 10:23:47	00:00:48	00:00:48
08.01.2007 10:24:13	08.01.2007 10:25:04	00:00:51	00:00:51
08.01.2007 10:25:04	08.01.2007 10:25:47	00:01:07	00:00:43
08.01.2007 10:25:50	08.01.2007 10:26:33	00:01:20	00:00:43
08.01.2007 10:26:35	08.01.2007 10:27:17	00:00:45	00:00:42
08.01.2007 10:27:56	08.01.2007 10:28:44	00:01:18	00:00:48
08.01.2007 10:28:45	08.01.2007 10:29:28	00:01:21	00:00:43
08.01.2007 10:29:31	08.01.2007 10:30:21	00:01:33	00:00:50
08.01.2007 10:30:21	08.01.2007 10:31:08	00:05:58	00:00:47
08.01.2007 10:31:08	08.01.2007 10:31:31	00:00:25	00:00:23
08.01.2007 10:31:32	08.01.2007 10:32:23	00:04:01	00:00:51
08.01.2007 10:32:31	08.01.2007 10:33:13	00:00:42	00:00:42
08.01.2007 10:33:15	08.01.2007 10:34:35	00:01:54	00:01:20
08.01.2007 10:34:00	08.01.2007 10:34:48	00:00:48	00:00:48
08.01.2007 10:34:48	08.01.2007 10:35:31	00:00:50	00:00:43
08.01.2007 10:35:34	08.01.2007 10:35:54	00:00:58	00:00:20
08.01.2007 10:37:47	08.01.2007 10:38:34	00:00:47	00:00:47
08.01.2007 10:38:54	08.01.2007 10:39:41	00:00:47	00:00:47
08.01.2007 10:41:19	08.01.2007 10:42:06	00:00:47	00:00:47
08.01.2007 10:42:06	08.01.2007 10:42:55	00:01:07	00:00:49
08.01.2007 10:43:11	08.01.2007 10:43:53	00:00:42	00:00:42
08.01.2007 10:43:56	08.01.2007 10:44:39	00:01:22	00:00:43
08.01.2007 10:44:40	08.01.2007 10:45:26	00:01:11	00:00:46
08.01.2007 10:45:28	08.01.2007 10:46:14	00:01:15	00:00:46
08.01.2007 10:46:16	08.01.2007 10:46:58	00:01:24	00:00:42
08.01.2007 10:47:00	08.01.2007 10:47:25	00:01:27	00:00:25
08.01.2007 10:47:29	08.01.2007 10:48:19	00:04:57	00:00:50
08.01.2007 10:48:19	08.01.2007 10:49:48	00:02:08	00:01:29
08.01.2007 10:50:12	08.01.2007 10:52:12	00:02:00	00:02:00
08.01.2007 10:51:44	08.01.2007 10:53:13	00:01:29	00:01:29
08.01.2007 10:52:24	08.01.2007 10:53:10	00:01:20	00:00:46
08.01.2007 10:57:09	08.01.2007 10:57:59	00:00:50	00:00:50
08.01.2007 10:59:41	08.01.2007 11:00:25	00:00:44	00:00:44
08.01.2007 11:00:26	08.01.2007 11:01:13	00:01:19	00:00:47
08.01.2007 11:03:22	08.01.2007 11:04:05	00:00:43	00:00:43
08.01.2007 11:04:07	08.01.2007 11:04:50	00:01:15	00:00:43
08.01.2007 11:04:52	08.01.2007 11:05:41	00:01:50	00:00:49

Fig. 17. Pneumatic delivery system (data interpretation): Start time (see first column) and end time (see second column) of the capsule for each individual process between 08:00 and 11:00 clock.

Global Interfaces

Regarding the global interfaces we were able to identify the time zone problem as the single greatest cause of efficiency loss on the basis of our simulations (see chapter 'Simulation of Intra-Organisational Interfaces...'). This problem could be alleviated through partial autonomy of the identified stations sensitive to this issues. These stations were subsequently permitted to partially issue their own shipping papers, which previously had to be created by the main station, a decision made easier by the fact that the manual control of the branch offices by the main station will be supported by the Interchain system in the future. The partial autonomy allows them (the branch offices) to specialise and thus reduce errors and increase work efficiency and speed - which is of utmost importance to a company depending on high-speed delivery for its business. Additionally, this greater self-sufficiency of the branch offices reduced possible sources of tensions over conflicting priorities about the processing of orders from different regions.

Summary and Outlook

As was shown throughout this thesis, the weaknesses identified in chapter 'Findings of the Weak-Point Analysis' were eliminated by three fundamental strategic improvements:

Through the Interchain system, we were able to establish work process transparency, improve the flow of information with the SCEM approach, and eliminate the cumbersome tracking lists, thus freeing resources for completing more orders within the same amount of time. Since the Interchain process is still in the process of being implemented and not all sections and branch offices have been fully trained in it, final evaluations of the improvements will only be available in 2008. However, first results of these changes have been extraordinary promising even without full implementation. The integration of branches, customers, and suppliers into the system will lead to additional complexity in the overall process. In order to manage the expected complexity in the future, I have recommended to Interturbine to consider outsourcing the Interchain system, as the Interchain system requires specially trained and highly paid people to maintain, and the IT department of Interturbine will already working at its full capacity merely to cope with the expected increasing amount of orders. A final decision has not yet been made, awaiting the results of a pertinent cost-benefit analysis. The Bonn investigation provides an informative insight into the issues to be analysed (see chapter by Bonn a. Kraft or Bonn, 2007, pp. 103-110). Furthermore, currently we are considering how to implement a selection process examining which suppliers will be able to meet tougher future standards for reliability. Especially, efforts to integrate suppliers into the Interchain-System is expected to be met with resistance by some of them, since out of necessity it will require them to make their internal work processes partially transparent to outside agencies - a loss of autonomy few relish (Frost & Sullivan, 2003b). However demands for increasing efficiency and time reliability by the customers may not leave them much choice, as only such 'open' suppliers will be seen as reliable enough to help reach these higher standards.

The pneumatic delivery system was able to eliminate unnecessary internal movements of the employees, resulting in an immediate and dramatic improvement of processing times currently more significant than the contributions of the other components. Many managers and employees were initially sceptical of such an 'old-fashioned' tool as a pneumatic delivery system. However, thanks to the unique nature of the airline supply industry, the most modern delivery system in the form of emails was not acceptable to the customers after all, any computer system can have internal problems and emails might be delayed or even vanish without anyone realising it. Conversely, physical messages are transported directly from one employee responsible for the order to the next, and even an unlikely breakdown of the pneumatic delivery system would be immediately noticed and replaced by simply walking to the next office. Once the new system was actually implemented, feedback of the employees was highly positive, as they are now able to complete more orders instead of being forced to travel back and forth between different sections. Previously, bottlenecks frequently arose as the shipping documents were only transported between the different departments every hour, but now these instances have been eliminated - most spectacularly in the case of the 'order processing' department.

Regarding the global interfaces, introducing greater branch office autonomy freed resources in the headquarters of Interturbine while giving the branch offices greater responsibility and autonomy.

We expect the most significant results of these changes once all improvements have been implemented and become fully established, as at the moment all of these are in a phase of transition. Only then do I expect a truly large reduction of cycle times, a transparent Interturbine, and an ability to guarantee $> 98\%$ successful deliveries before the agreed deadlines (see e.g. chapter 'Interview' and 'Preliminary Resume'). Nevertheless, we can see that despite a drastically higher amount of orders it was possible to stabilise or even improve the average processing time. [15]

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[15] Part of the performance improvements can also be traced back to an enlargement of the number of items within the warehouse.

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Focused Interviews

SCEM at Telecommunications Service Providers – Useful or Superfluous?

T-Systems International GmbH

Jochen Hagen - Information and Communications Technology (ICT) – Expert
In der Raste 26, 53129 Bonn, Germany

Jochen Hagen, born 1969 responsible for VPN Services within T-Systems International GmbH and a part of the telecommunication industry for more than 10 years. In 1998 Jochen Hagen finished his successful study with the title Master of Computer Science – at Bonn University and recently his MBA at the Erasmus University in Rotterdam. He broadened his experiences in the telecommunications industry at AT&T, Global Crossing, KPN/ Qwest and Level 3 in the Netherlands, in London and in Germany. In 2004 he joined T-Systems International GmbH as EVP for Product Management IP. He has project leadership of several strategic projects in T-Systems International GmbH as e. g. launch of MPLS based IP VPNs, VPN Strategy and IP Transformation. Since 2005 Hagen is responsible for VPN Services of T-Systems Business Services, which is serving the Business Customer Segment of Deutsche Telekom. He takes the responsibility for 60 people and revenue of approximately 1 B €.

Ijioui: Which goals does T-Systems pursue?

Hagen: Set as a strategic goal, T-Systems will be going to lead and drive the information- and telecoms-industry as Europe's largest integrated information and communication technology (ICT) supplier. The goal is to achieve this in the business customer segment – which is addressed by T-Systems within the Deutsche Telekom Group – by developing the core business 'telecommunications' especially in the area of infrastructure by growing the ICT-solution business leveraged through standardised IT-services focussing on the medium enterprise market and by extending the business process outsourcing offer for multinationals. Appropriate measures were taken, addressing revenue by increased integration and innovative convergence, and achieving a respective reduction in cost as well as a better customer perception by operational improvements especially in the reference to production, IT/processes, procurement and personnel.

Ijioui: What do customers expect from T-Systems?

Hagen: Although the range of customer segments addressed by T-Systems is rather broad, one is able to filter and shape out certain demand-clusters of core-expectations. It seems to be fundamental to support the customer to focus on his core-business and not only to relieve him of as many non business relevant activities as possible but also to manage these under assumption of the respective and appropriate responsibilities. A second important aspect is the extension and increase in business flexibility in respect to the supplied service. The services do not only have to simplify the internal and external co-operation with customers and suppliers, but also have to be more and more the foundation for a fast, efficient and flexible adjustment of the respective business model. Additionally to these requirements which concern the entire value overseen by the customer, basic deliverables have to be fulfilled such as the possibility to access content and applications varying in availability adjusted to the respective needs. Basic if not trivial, also in this business the price/result ratio has to be healthy and competitive.

Ijioui: Where does T-Systems see the greatest challenges of the TK-industry in the next few years?

Hagen: Convergence represents the largest challenge. The already recognized convergence of networks via IP and of services via MPLS continues to expand – VoIP is only the beginning and one of the symptoms. As direct consequence products, production-models, -techniques, IT, processes and necessarily also organizations converge. The industry is about to perform a quantum transition whereby one has to prepare to be part of it. Not only the technical progress in particular is a Challenge, but also to transform and migrate the business model according to the new conditions and markets within the given timeframe.

Ijioui: From your point of view, which are the most important aspects a company needs to keep in mind to survive in the highly competitive telecommunication service industry?

Hagen: As a direct consequence of the question regarding the challenges we have to pay attention prioritised to changes within fundamentals of the business and the business models. The basis of the telecommunications market becomes increasingly commodity. A value creation moves in so-called shared services and process management and thus into new markets, which can only be sufficiently addressed by new business models.

Ijioui: Is a well-organized service-oriented supply chain a prerequisite for fulfilling present demands for speed and quality by the customers?

Hagen: Absolutely. Following the customer requirements described above, to gather, recognize and manage information about the Supply chain, classically compound from heterogeneous systems over different levels, in each stage of the process in real-time turns more and more into a necessity. Likewise, as in the case of an arising problem one would expect an ad-hoc solution – one has to be able to initiate reasonable changes of the supply chain especially short term notice and reactively regarding collaboration issues. It should be mentioned that a supply chain basically does not differ in a service surrounding environment fundamentally from other services. The obligation to supply from end to end and partial aspect view exists here likewise - a supply on time is a quality criterion in each case and a possibility to differentiate as by delivery periods, which are below the usual industry average.

Ijioui: Which importance does the time factor play in the telecommunications industry?

Hagen: Time is money! - Early supply means revenue without delay and improved planning possibilities; early error recognition in the system means reduced costs and higher customer satisfaction. At the same time the factor time is embodied and woven into the structure of the Business model and experiences the already described metamorphosis from reactive batch processes, to on-demand and real-time offer and production.

Ijioui: Which positive results would you expect from the introduction of a SCEM system concept at T-Systems?

Hagen: Such a concept would bring a new dimension of transparency and control possibility. Remarkably here that this would not only lead to immediate internal improvements - e.g. elimination of entropy and possibilities for automation - but also generates respectively similar external effects. We would expect concretely a more positive customer perception, a cost reduction and the possibility to co-operate more effectively with suppliers and customers - keyword B2B integration -. In the logistics industry this has been recognized for a long time already and we also think very intensely about how we can develop, construct and implement such a process-monitoring- and event-management-system effectively and efficiently.

Ijioui: Is such an approach of interest for T-Systems, or has such an approach been implemented already?

Hagen: To my knowledge there is no such concept implemented as of today, although today's planning overarches pure interest by far. As described above T-Systems did not only recognize the advantages of SCEMs but continued and enhanced the concept within the planning of an extended and fundamentally new architecture (product, production, IT and process). A modularized portfolio, separated according to production and selling view contains parameterized the necessary process components on which a respective seamless order to bill chain is based. These pieces of process are steered and monitored by an architecture-immanent BPM. A supply chain management is inherently part of the production-process-parameters which are embedded into the fulfilment-process. The monitoring and possible ad-hoc controlling of this process chain in conjunction with an entirely new on-line~ and portal~ design, not only allows in time reaction to potential events but also the quasi instantaneous supply of services. At this stage however the incomplete process- and IT integration of third parties remains problematic, and sometimes forces us to leave the path of automation and return to somewhat conventional methods.

Ijioui: To meet the challenges of the industry, it is of vital importance to periodically re-examine and optimize one's business processes. How important do you consider a continual reengineering concept to be for T-Systems?

Hagen: It seems out of question that an enterprise, which wants to sustain a competitive position within the ICT market – consider that Moore's Law has been undercut meanwhile - must improve continuously. A corresponding CIP (continuous improvement process) is in development and about to be finished. Since the entire architecture (concept) has been developed in a modular manner, the (conscious) possibility of adjustments opens up within the entire system if necessary – this does not only apply for process and IT but also for alterations within the product-catalogue or production elements. Besides the manual triggers which appear almost trivial it is reasonable to install a benchmark-oriented threshold logic, which spotlights - as exact and profound as possible asymptotic to the process chain -, for example by means of a cockpit the respective improvement potential. Even though already thought of however today regarded as utopian remains the desire for an AI supported automatic re-engineering of the relevant process-clusters.

The Change of REFA Methods by Supply Chain Event Management Considering Globalisation

REFA Bundesverband e.V.

Group Interview with Gerd Conrads, Maruan Issa, Oliver Störmer
Emil-Figge-Straße 43, 44227 Dortmund, Germany

Dr.-Ing. Gerd Conrads, born in 1953, studied Mechanical Engineering at the RWTH Aachen and graduated in 1982 in the field of automotive engineering. After the study, he worked as a design-engineer in an engineering-office. After four years, he returns to the Institute of Industrial Engineering and Ergonomics at RWTH Aachen, where he prepared his doctoral work. 1992 he received his doctoral degree (Dr.-Ing.) from the RWTH Aachen University. After his time at the university, he works as Senior-Consultant and the last 6 years as the Managing Director of the REFA Association for Work Design/Work Structure, Industrial Organization and Corporate Development in the region north-west of Germany.

Dr.-Ing. Maruan Issa studied Mechanical Engineering at the Ruhr University of Bochum and graduated 2000 in the field of Process Engineering (Dipl.-Ing.). He worked for the Fraunhofer Institute UMSICHT in Oberhausen where he prepared his doctoral work. 2007 he received his doctoral degree (Dr.-Ing.) from the University of Duisburg-Essen. Since May 2007 he works as an independent consultant. He cooperates with REFA and is the REFA-Representative to the Middle East.

Prof. Dr. Oliver B. Störmer, was working the last 4 years as board of directors at REFA Bundesverband e.V., Darmstadt. The REFA-Association for Work Design/Work Structure, Industrial Organization and Corporate Development is a private, non-profit organization. It provides training, further education, consulting and coaching in all sectors of production, administration and the service industry.

Prof. Störmer received his Finance Doctor and Professor degree in Switzerland where he was born in 1966 near Geneva in the French part of the country.

Ijioui: Which targets pursues the REFA with the SCEM concept?

Conrads, Issa, Störmer: Today's ergonomics are strongly focused on the working and acting man. It often considers economical correlations and objectives only to a limited extend. Hence the aim has to be the combination of humanity and rationality in process-oriented systems of ergonomics, where adequate methods and tools (of ergonomics) are used and both aspects are taken into account sufficiently.

The economic benefit of using systematic methods has to be pointed out practice-oriented to achieve an intensified use of ergonomics to create effective and efficient working processes. SCEM helps to control a current challenge for the service in customer-supplier-relations. Since more than 80 years the REFA association works on the task of providing transferable aids and methods, developed and edited by experts, for the practitioners in companies. Here the accent is always on the classical corporate goals: to reduce costs, to save time and adhere to deadlines and to improve product and process quality. SCEM aims, against the background of the CRM (Customer Relationship Management), at the improvement of the relations between company and its clients. These relations are also influenced by successful compliance of the supply chains success factors: to deliver within the specified time, quality according to the agreement and acceptable costs. As a consequence SCEM, as a strategic concept for corporate management, represents the logical expansion of the REFA goals on the supply chain. The objectives of the REFA are to use the steering events of the SCEM concept to design structured processes and also processes which can be planned more reliable and efficient by means of precise planning of procedures and reactions, and to develop a methodical proceeding.

Ijioui: In which way can customers profit of the REFA?

Conrads, Issa, Störmer: The REFA methods and their use in best-practice applications support the process owners in manufacturing and service companies to solve their problems. Exchange of experiences and edited practical knowledge to solve these problems is provided in seminars. Objective of the REFA is, by means of efficient and effective design of integrated work systems, to make modelling of the herewith associated processes possible and assessable regarding their efficiency and value creation.

Ijioui: How can the REFA help to manage the dynamic of globalisation?

Conrads, Issa, Störmer: SCEM is a method for complex and global customer-provider relations to control not planned occurrences by way of determined guidelines. The common statement "the normal procedure is the disturbed procedure" is valid in this case, too. It emphasizes the need of planned dealing with disturbances. In particular in context with global supply chains, where men as dynamic factor are hard to standardise, such methods become more important. The acting individuals have to be described in their dynamic within the work system and critical factors have to be identified. Further, the work systems have to be described considering the aspects of globalisation to derive principles for design and relations. The mutual connection of the systems (input-output) has to be characterised as process model. The view on function and organisation has to be associated relationally. An adequate calculation of the process cost is necessary to maintain a continuous controlling which is oriented towards the global needs. Looking at a region like the Middle East, considering its prevailing business culture we want to show the potential of implementing such a SCEM system. In this region the companies are conglomerates with diversified portfolios, working with international suppliers a long time. In other words: one can find complex network structures. An example for such a SCEM network in the service sector is the construction and operation of the world famous hotel "Burj El-Arab" in Dubai and its service enterprises. The sensibility regarding company data is a critical success factor for the acceptance of SCEM, since companies derive integrity/reliability of logistics or engineering enterprises in a network from this factor. More and more Arabic companies are participating in international business. It is necessary to create data transfer according the motto "as little as possible, as much as necessary".

In this context one has to see the efforts of the Dubai Ports World (United Arab Emirates) trying to take over the management of six important US-ports and the port of Hamburg.

Ijioui: How necessary are embedded controlling and monitoring in processes and operational systems?

Conrads, Issa, Störmer: Process monitoring of key indicators (management ratios) need to be established as a feedback to process owners and process participants in a secured way. Planning data, method managed and produced, allows all responsible and participating persons monitoring their capability and performance inside the global supply chain. REFA intervals are the reference basis. They are described and atomised in value added units to produce significant key indicators.

A major goal of these key indicators is to open and support organisational clearance. Methods and method-based proceedings need to be established during conception and arrangement. They have to be balanced between operational and human covered aspects. This is the contribution to make the human factors plannable. This method assists the preparation of close-to-reality planning data.

Ijioui: How close did you get involved with the major aspects of SCEM in reference to SCM?

Conrads, Issa, Störmer: In the opinion of REFA there is a huge portability of the classic REFA methods to this new and wide area of application. In particular by an analytic approach with support by relevant auxiliary systems and tools a large comparability and transferability with well-known procedural models are reached for the organization of process orientated organisations.

Ijioui: How does REFA stand to the SCEM idea and which connects REFA methods hereby?

Conrads, Issa, Störmer: Humans as dynamic organisation factor to regard here offer itself. Human's behaviour on typical events without defined guidelines is classically intuitive and experience-led different. The reactions on events can be defined previously with SCEM and according to monitoring and advising functions. Events affect processes in positive and negative ways. The human's qualification must be ensured for that kind of events. Simulations and business games are valuable tools. Social standards and employment law are naturally considered.

Ijioui: Do humans have to be replaced meaningfully by automation?

Conrads, Issa, Störmer: No, humans are not replaceable in this SCEM view. As shown in the closed past deserted productions or fully automated procedures have less success in handling interferences and unexpected events. They create higher loss costs and have more difficulties in their efficiency. Looking on humans as production and service element they can not be replaced in most processes completely if they act as high performer. Often it is also not appropriate because of expenses and reasons of flexibility. Action knowledge and holistic thinking of humans offer irreplaceable advantages. Determination of human based working capability and efficiency is one main aspect of REFA's business. For this an adequate database with comparative data for typical REFA intervals is necessary. Expiration steps must be verified and validated by means of ergonomical methods to be defined and the determined data on that referred to. An essential structure with SCEM data for the planning of creative and event-referred processes would be an ideal planning aid, which applies to develop it together with interested enterprises. To develop a standardized SCEM network forming process - under use of established REFA methods - is an avowed goal of the REFA. Which factors for the human achievement in the SCEM are substantial and which are transferable, is cooperatively and scientifically studied together with relevantly interested enterprises and university institutes in expert circles and has to be determined in line with standard usage at the same time and developed further.

Focused Interviews

Supply Chain Event Management by FORD of Europe

FORD of Europe

Bernd Südel
Manager – Supply Chain Management
Henry-Ford-Str. 1, 50735 Köln, Germany

Bernd Südel, after graduating from University of Passau in 1987 he participated in a 12 months internship in the US working as part of the office staff at Intertrans Corp in International Freight Forwarding nearby Atlanta airport. After returning to Germany, he was hired by Ford Motor Co in Cologne where he spent 18 years and progressed through various areas of logistics. He started as an analyst in Outbound Distribution and in Palmela (Portugal) launched the Inbound Material Logistics for their Joint Venture with VW. His management positions include positions in Logistics Planning, as Plant Material Logistics Manager and most recently the more Senior positions as Manager Production Scheduling for all European Vehicle Operations and Supply Chain Manager.

Ijioui: What are the strengths of FORD of Europe when compared to the rest of the automotive industry?

Südel: A significant strength is Ford's manufacturing efficiency which has been evidenced repetitively in the Harbour reports. 3 of our Vehicle Assembly Operations (Cologne, Saarlouis and Genk) were amongst the Top 5 most efficient European Assembly Plants (source: Harbour report 2005) with Cologne taking the top. It only requires 12, 48 h to produce a Fiesta/Fusion unit here in Cologne.

Ijioui: What do customers expect from Ford of Europe?

Südel: Traditionally customers expect "excellent value for money" when they think of European Ford products. However, the driving dynamics and precise steering are benchmark within the industry and particularly recognised by the automotive journalists. With our latest products like the S-Max and the new Mondeo following the new kinetic design language Ford is successfully reaching out to new customers, who like the premium appeal together with its design and driving dynamics. These customers are making a deliberate emotional choice in favour of the new Ford products. Customer perception is changing and these customers are proud to show off in the latest Ford product.

Ijioui: Where does FORD of Europe see the greatest challenges for the next few years within the automotive industry?

Südel: There are multiple challenges with priorities often changing due to customer perception, media awareness and political/environmental direction. Currently the environmental CO2 discussion and the implications for the automotive industry are dominating the media and hence will influence customer perception. On the other hand "globalisation" represents a tremendous opportunity where FORD of Europe has taken a successful sales lead in the rapidly growing Russian Market. Supplies from the Far East offer opportunities for lower component prices, but simultaneously do these extended value chains represent a risk as it becomes more difficult to establish robust "just-in-time" logistic processes. Establishing precise forecasting systems reflecting true customer demand is one of the associated challenges, as extended supply chains leave only 2 options:

a. "Build to Forecast" (and take the risk of disconnecting the product offering from the customer demand) or
b. "Build to Customer Demand" (and accept the risk that a lot of material needs to be expedited by airfreight and hence generating an unaffordable cost position).

Ijioui: To meet the challenges of the industry, it is vital to continually re-examine one's work processes. How important to you is a continual re-engineering concept for this purpose?

Südel: About 15 years ago FORD commenced its overhaul of the manufacturing processes defining and implementing the so-called FPS (FORD Production System), which has been using the worldwide recognised Toyota Production System as a template and adding specific Ford ingredients.

Six Sigma deployments have been added as a significant enabler to implement a continuous improvement mentality within the workforce. As a consequence all processes are being monitored and screened for improvement with a focus on delivering manageable projects in terms of timing and size. Also project replication opportunities are then being communicated and implemented. However, also re-engineering opportunities with a larger scope have been pursued as there is our GPDS (Global Product Development System). It is summarizing the best approaches from across the Ford brand portfolio including Mazda, Volvo, Jaguar and LandRover in developing and launching new product.

Ijioui: Which problem areas within the automotive industry are especially time critical?

Südel: In general the automotive industry is operating at minimal inventory levels maximizing JIT or in-sequence deliveries. The consequences of late deliveries can leave thousands of employees with nothing to do. Hence, the external logistics process needs to be as robust and reliable as possible providing real-time visibility of the supply status within the 4-walls of the factory as well as the in-transit supply. A detailed logistics plan for every part is a prerequisite and the ability to recognize any "off-standard" supply situation instantly is a key contributor. Whilst we have gained excellent control of the inbound supply by road, we continue to suffer from an unreliable rail infrastructure in particular in France.

Also, the supply base needs to be qualified and committed to serve the customer. Key enablers for implementing a capable supply base are audit processes executed by Ford of Europe validating throughput and also the logistical competence of any supplier. Lately, the financial strength of a supplier has become a problem area. Supplier liquidations demanding emergency resourcings have occupied lots of resource and represent a permanent threat to the operations

Ijioui: What strategies are being pursued by FORD to ensure delivery on time under all circumstances?

Südel: First of all Ford of Europe is sharing real-time inventory and demand data with its suppliers and Lead Logistics Partners. Additionally, the external transportation network represents a planned and fully controlled delivery process. In case of emergency, any kind of delivery is being expedited to avoid a production line-stop or building vehicles that require retrofit of missing components. Expedition of goods may be done by …

- adding a 2nd driver to a truck avoiding the truck to take mandatory brakes
- using smaller and faster "bullet vans" (Ford Transit derivatives)
- scheduling overnight airfreight or

- using "on-board-couriers" and
- by chartering dedicated aircrafts/helicopters

Ijioui: Does Ford of Europe have strategies that enable the company to react to unforeseen events within the supply chain in the shortest possible amount of time?

Südel: Various alternative strategies exist and the right strategy is usually selected by gathering the Subject Matter Experts analyzing the magnitude of the problem and trying to minimize the impact for the customer as well as minimize the financial exposure of the company. Below on overview of the strategies as well as a high level assessment of the pros and cons:

Table 1. Overview

Strategy	Pros	Cons
1. Expedite transport	No late delivery to customer	Expensive
2. Build vehicle "in-complete" and retrofit missing components	Assembly Process, Inbound Material Flow and Supplier Schedules remains stable	Expensive, late delivery to customer and risk of quality issues , applicable to no job-stoppers only
3. Re-schedule Production sequence	Applicable to job stoppers,	Customer delay, remaining build sequence may become unbuildable by exceeding capacity constraints
4. Stop-Production	Protects quality	Expensive, late delivery to customers
5. Use alternative part	No late delivery to customer, Assembly Process remains stable,	Only feasible by giving the customer an alternative component that represents an upgrade (i.e. better radio, better speakers)

Ijioui: How important do you consider to be an IT-supported monitoring and controlling of an automobile-oriented supply chain (from the customer order to the final delivery of the car)?

Südel: So far we have learnt all of the inbound supply chain processes within FORD of Europe. Of course, the outbound supply chain process is of equal importance. Providing the dealer with real-time information the status of his order is essential for achieving excellent dealer/customer satisfaction. However, it sometimes may be beneficial to not show the progress with all its minor variances, but sub-press unnecessary "noise" as the ultimate promised delivery date can be recovered and stability in the delivery promise provides better credibility than too many confusing status updates.

Ijioui: How common is knowledge about "Supply Chain Event Management" within Ford of Europe?

Südel: Whilst the expression is not commonly used within Ford the basic elements are well known and deployed to a mature level. Event sharing based on EDI in/outputs with both internal and external partners is reality within Ford of Europe for many years. This applies to both our inbound material flow supply chain as well as to our outbound distribution supply chain.

Ijioui: What kind of positive results do you expect from the introduction of a Supply Chain Event Management System concept at FORD? Would such an approach be of interest for FORD, or has such an approach even been implemented at the company?

Südel: As mentioned before, we believe to use this concept for many years and have seen great improvements from implementing these. We enjoy reduced inventories with faster inventory turns, improved quality of our product, improved manufacturing stability and hence better productivity and for the customer/dealer the evidence is improved on-time delivery of our final product, which is a great asset in the relationship between dealer and retail customer.

Supply Chain Event Management in the Financial World

Ernst & Young AG

Wilhelm Schreiner
Advisory Services
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Wilhelm Schreiner, Dipl.-Kfm, is the responsible within Ernst & Young Advisory Services Germany for Supply Chain Management and Procurement. Wilhelm Schreiner led several projects in procurement, inventory and supply chain management in different industries. Before Ernst & Young he was responsible project manager within Deutsche Post World Net / DHL for implementing e-Procurement and purchasing manager in technical purchasing within BASF AG.

Ijioui: What are the strengths of Ernst & Young?

Wilhelm Schreiner: Ernst & Young is known as a global leader in professional services with 114.000 employees, in 700 Locations in over 140 Countries all over the world. With revenues of 18, 4 billion US $ in 2007 Ernst & Young is serving clients across all industries. Ernst & Young's core competencies are well known in the area of assurance and tax services. In addition, Ernst & Young has successfully established a new service line, covering the area of Transaction Advisory and Risk Advisory Services, the so-called assurance related advisories. The main focus within this consulting service area relies in giving our customers the right support and answer for questions regarding process, organizational and technical risk consulting is bundled. Coming from the CFO-Agenda Ernst & Young attests the correctness of figures, gives guidance to reduce tax payments, supports companies in transaction and risk management topics. Further Ernst & Young decided, due to high request by clients – to additionally build up advisory services for performance. All performance related solutions are concentrated within Business Advisory Services. In detail, Business Advisory Services offers Management Consulting in Finance Transformation, Performance Management and Operational Effectiveness, where e.g. Supply Chain Management plays an important role. Ernst & Young is convinced that the CFO has to take care of the operational processes to keep his finance requisitions managed in a sufficient manner. Giving an example: if a CFO wants to optimize his working capital, the company could do this most efficient by reducing inventories. Reducing inventories could only be done by changing your supply chain operations, changing the warehouse strategy or changing the border of push and pull within your value chain levels. In total, the strength of Ernst & Young is to leverage its expertise and experiences to help and support the CFO with any questions, to strengthen his company's performance with an integrated advisory offer. Key is finding the balance between risk and performance – between protecting and creating value – to run finance.

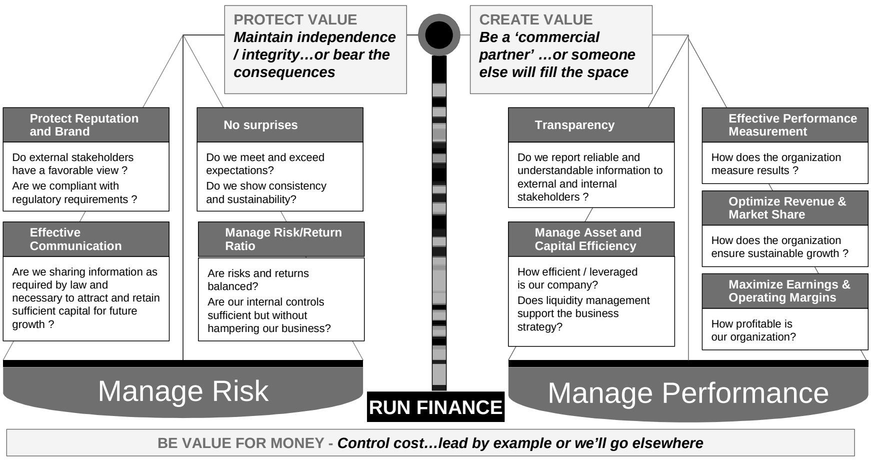

Fig. 1. Balance between risk and performance

To meet this goal, it is important to understand the pre-condition and what the supply chain calls for. The main focus relies on building up and establishing high efficient processes, organizations and systems supported by defined controls – events – measuring performance and avoiding risks.

Ijioui: What do the potential customers expect from the Ernst & Young?

Wilhelm Schreiner: Working in the finance area demands integrity, professional competence and quality in everything we do. Ernst & Young offers customized solutions based on worldwide standardized approaches and methods. The client is looking for an integrated approach that covers all from finance to operations. Therefore, Ernst & Young has added the supply chain management solution demand to the finance demand. Knowing that the finance function is mainly thinking in money measures and the supply chain function in pieces, Ernst & Young aims to combine Euros and pieces. Coming from optimizing income and/or liquidity the Ernst & Young supply chain advisory solutions are adapted to improve these positions. After successful and sustainable improvement these optimized effects are obvious and can be shown in balance sheet, P&L and cash flow showing up sustainability.

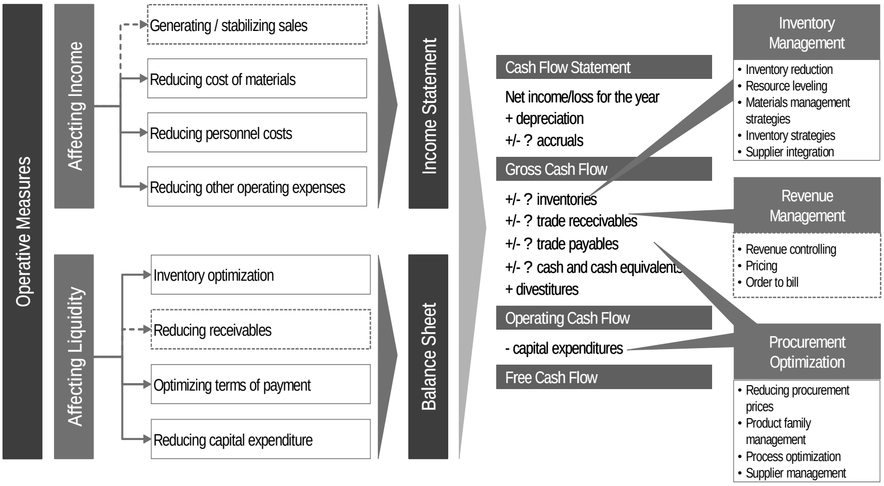

Fig. 2. Global illustration

Thinking about optimizing finance requirements by supply chain management, several levers are given. To optimize company's income statement, the supply chain function is able to support this by reducing cost of materials using various procurement methods and levers, or reducing personnel costs by lean and efficient supply chain processes and organizations. Optimizing the balance sheet with the help of the individual supply chain function, three levers are given. The reduction of inventories by optimizing lot sizes and inbound logistics strategies for raw-, production- and MRO-material, the optimization of the production to reduce work in progress and the development of an efficient distribution network including warehousing and transportation to keep the right stock levels on customer side. Even the enhancement of terms of payment conditions – to increase supplier liabilities – and the reduction of capital expenditure – to reduce purchase prices of assets – through procurement function optimizes the balance sheet. Both result in higher liquidity and a better cash flow.

Supporting clients to increase income and liquidity and herewith shareholder/stakeholder value Ernst & Young provides the following supply chain management solution. There are three overall strategic goals supported with this approach:

- Cost Leadership
- Process Leadership
- Capital Efficiency

Beneath the areas mentioned above, Ernst & Young's approach offers its clients supply chain strategy development, supply chain core processes "planning, design, source, make, deliver", inventory management, quality management and the supply chain infrastructure divided in organization, IT-systems and controlling. All services mentioned here are shown in the Ernst & Young Supply Chain Pyramid below in combination with the Ernst & Young advisory approach for all related industries:

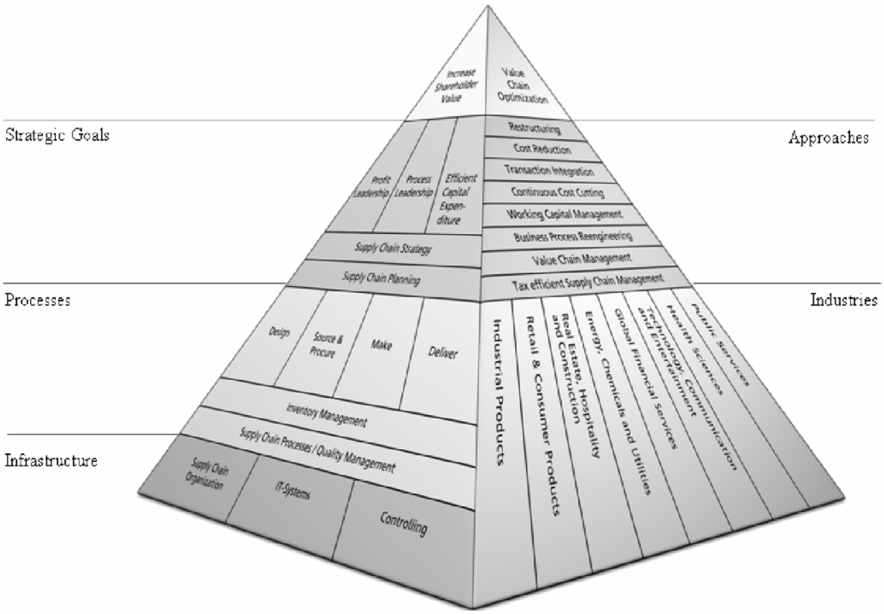

Fig. 3. Ernst & Young Supply Chain Pyramid

Ijioui: Where does Ernst & Young see the greatest challenges for the next few years?

On the one hand Ernst & Young sees challenges in the impact of the worldwide increasing globalization effects like e.g. cost pressures, changing business needs and the impact of new technologies. On the other hand there are further upcoming environmental risks everybody has to deal with, beginning with earth warming and terrorism. In addition, there are also tendencies to new legal and regulatory matters.

- New demands and new possibilities create a gap between current performance and required performance.
- New demands may place a greater emphasis on the quality, cost or value for the business that is associated with a given outcome.
- New opportunities, arising from the potential offered by technology to automate tasks or empower people, together with greater globalization redefines what good should looks like.
- The supply chain function must therefore continually transform its capabilities into a response to the demands and opportunities brought up by constantly changing environment.

All this makes companies with global and complex supply chains fragile. Other more operational challenges come out of limited transportation capacities and growing transportation prices, which limits further globalization efforts and ends in higher prices. Even the upcoming growth of interest rates forces changes within supply chains.

These issues contain risks for the individual supply chain. Potential risks within the processes need to be controlled, which could be set by events. All deviations need to trigger an event to give companies chances to solve the issues and prevent the risk. The overall level between risk and performance has to be adjusted according to changing environmental issues in order to guarantee a solid and save supply chain.

Ijioui: To meet the challenges, it is vital to continually re-examine one's work processes. How important do you consider a continual reengineering concept to be, for this purpose?

A continual reengineering of the operational work processes is essential to cover business partners' needs. Changing market requirements on customer and supplier side, economic trends, new technologies and M&A activities forces companies to rethink and change their processes. Therefore it is necessary to have a continual reengineering concept to avoid process changes in a permanent way.

Every company should have it's processes in a lean and well documented way. It is necessary to well define mature processes for a defined period. Beneath M&A or restructuring activities, where process redesign is a must, companies have to analyse trends. To demonstrate this topic, we should think about two examples:

- Procurement processes have been mature, stable and IT-supported for years. With the upcoming trends of the new economy with it's IT-systems like e.g. eProcurement or eSourcing Tools, most procurement processes had to be redesigned to cut costs and lead times. Implementing electronic catalogues and related workflows enable the automation of processes and cut down headcount costs. eAuctioning tools created new chances to reduce companies purchase prices.
- Logistic processes had also a lot of changes coming with the new economy. Buying goods directly from an electronic catalogue with short lead times, or fulfilling a customer demand for over night deliveries in smaller packages. To cover these requirements suppliers had to restructure their whole outbound logistics to deliver in small commissioned overnight packages. Because most suppliers did not want to pay for these new processes, suppliers implement cross docking stations. Cross docking facilitates the suppliers to commission goods without storing them from trucks to smaller vehicles. Companies who could not change their processes lost a lot of orders.

To act in the right way or to start reengineering at the right point of time, companies need to have a process reengineering concept in place. They also need to have an eye for trends and innovation, regarding supply chain event management systems. The right set of events enables companies to see that logistic costs are raising and the capacities might not be sufficient. This observation will force companies to rethink their logistic concepts, as well as their production concepts. These trends combined with global supply chains just-in-time concepts will lead to new warehouse concepts to reduce risk. On the other hand the warehouse level has to be well set because of raising interests.

Therefore processes have to be well designed or at the right time redesigned. Processes have to be planned exactly. Control mechanism and events have to be set up to maintain and control the processes. Adjustments could be carried out on time and adequate made.

Ijioui: Which problem areas within the financial world are especially time critical?

The finance world has a lot of time critical issues. One of the most important, esp. for public traded companies is to focus on cash, as Private Equities is able to buy every company in the world. Every company, which does not manage its cash efficient, is potentially endangered. Even non-traded companies have to manage their cash to finance transactions or other capital expenditures with own money.

To focus on cash, Ernst & Young advances the view that today's CFO's need to have efficient operational processes as an additional topic on their agenda. The CFO can not be just responsible for the controlling of figures operational units set. He has to start verifying the set targets and figures of the operational units. Especially to avoid risks and assure the performance of the whole company the CFO has to expand his agenda.

If you think about cash generating through efficient processes you have to optimize working capital. This means lean and efficient order to cash, purchase to pay and forecast to fulfill processes. All these processes have to be measured with sufficient Key Performance Indicators (KPIs), the right control mechanism and events to keep the processes in a sustainable manner.

Ijioui: What strategies are being pursued to ensure delivery on time under all circumstances?

To assure delivery under all circumstances means guaranteeing 100% schedule effectiveness to the customer. In this case a sufficient risk management is necessary. Every risk within the supply chain has to be identified. Events and the right controlling system have to be in place. For every single risk a solving strategy has to be defined and the lead-time has to be adjusted according to the strategy. Setting up this mechanism as an early warning system risks could be seen early enough to react in an efficient way. The entries of potential risks have to be simulated and combined to each other. Companies have to figure out what could really happen and if they have a chance to fulfill their scheduled dates. In case there is any doubt that 100% delivery is on time, the only solution is to build buffer stocks.

These buffers have to be applied at the weak points within the supply chain to avoid late time deliveries. The height and intensity of the buffer relates directly to the potential risk. Over all (buffer) stocks are just aspects of risk management.

Ijioui: Do you recommend your customers to have strategies in place that enables their organization to respond to unforeseen events within the shortest possible amount of time?

Yes of course, it is obvious that supply chains are very globally aligned today. This means that today's supply chain management is spread over a larger geographic area. Managing this supply chain network in an efficient way opens up many potential opportunities to meet customers needs. Within global supply chains there are also many potential problems and pitfalls hidden of which companies have to be aware of. These issues could be clustered based on Dornier in four forces, which drive the trend towards globalization:

- Global Market Forces

- Technological Forces
- Global Cost Forces
- Political and Economic Forces

Global market forces involve the pressure created by foreign competitors, as well as the opportunities given by foreign customers. Technological forces are related to the products themselves. Various subcomponents and technologies are available in different regions around the world. Successful firms need to have the ability to use these resources quickly, efficiently and at the right time. Global Cost Forces often dictates global location decisions where for example the focus relies most on low cost country sourcing. Political and economic forces affects the key drivers of globalization, e.g. exchange-rate fluctuation, regional trade agreements etc.

It is obvious that all these forces are challenging strategies that enable companies to react to unforeseen events within the shortest possible amount of time. For this case Ernst & Young offers individual strategies to avoid risks, or to manage scenarios to solve the issues, which are current for the customer. Ernst & Young has the resources and professional expertise to develop both hedging and flexible strategies. Especially flexible strategies like production shifting, information sharing or global coordination are very sufficient for successful handling the issues mentioned above.

Ijioui: How important do you consider to be an IT-supported monitoring and controlling of business processes?

If you think about global supply chain, monitoring and controlling of business processes is hardly feasible without any support of IT-systems. Managing such complex processes across company borders, including supplier and customer processes, is not manageable manually.

Complex processes like this need the support of IT-systems like ERP-systems and cross company related collaboration tools to establish a strong, lean and stable supply chain process. If process related systems are in place, working, monitoring and controlling points have to be defined and aligned with the company's strategy. These tools are called, by Ernst & Young, Supply Chain Event Management Tools. Such tools have different advantages:

- Through inter-organizational monitoring, the current state of e.g. an order can be surveyed and compared to intra-organizational or target data. Discrepancies and interruptions are detected promptly, which enables the company to make the right decision and take action on time.
- Competitive advantage because of enhanced transparency and a fast, efficient information flow.
- Enabling specific process management because of enhanced information transfer along the supply chain.
- Real-time decisions.

- Monitoring and controlling build the foundation for optimal process (re)-engineering and –optimization, which - in consequence- leads to cost savings, free capacities and finally to a higher process quality.

In summary IT-systems for monitoring and controlling are absolutely essential for managing global supply chains in a sufficient manner.

Ijioui: How common is knowledge about Supply Chain Event Management within the Ernst & Young AG?

As mentioned before Ernst & Young possesses the expertise, the experience and knowledge about supply chain event management, because the balance of risk and performance is the strategic consulting focus of Ernst & Young. Traditionally the assurance companies are strong in risk management, means to advise customers in avoiding or dealing with risks. Potential risks within processes are forecasted by events to control these process steps and act in the right way, if potential risks take place.

With the establishment of the Business Advisory Services, Ernst & Young's supply chain management solution became one of the core solutions for it's demanding clients. Combining the supply chain competency with the risk advisory approach, supports our clients to establish, develop and sustainably enhance a stable and secure supply chain function. In addition, the right monitoring and controlling process within the supply chain creates sustainability only if a supply chain event management system is in place.

An example from the area of inventory management will demonstrate how a supply chain event management system needs to look like. As mentioned before inventories or buffers are organized by companies to avoid delivery shortages and therefore can be defined as an element of risk management. From supply chain and cost perspective these buffers or warehouses have to be aligned with the right products, the right logistic concepts and an optimized level of stock. Defining this level correctly demands advanced supply chain expertise.

To balance the risk and the supply chain performance issue ranges should be defined for the level of inventory. At this point of time a supply chain event management system should be in place to guarantee that the product stock level are within the defined ranges, at all times. If the stock level deviates from the defined range the event management system has to signalize this. All these events have to be aligned according to the solving strategies to manage the risk/event properly. Strategies could be out listing or adapting the disposition parameters when the product is on a new stage of the product life cycle for example.

Ijioui: What kind of positive results do you expect from the introductions of SCEM concept? Would such an approach be of interest in the financial world?

The most positive result of implementing a supply chain event management system is to have the chance to see risks at the right time, as early as possible. This is the only way how you can verify the right solutions or strategies to avoid these risks. Further these systems guarantee sustainability of processes and targets because the set up of process control mechanism and KPIs can be monitored and driving an event, if there are irregularities within the processes or setting up targets. It leads companies directly to taking action, bringing the processes and targets back to the original set up. So that this information can be used to improve the efficiency and stability of business processes, which directly results in a higher profit and customer satisfaction. Especially the impact of SCEM in the financial world is getting more and more important. Focussing on cash and cost out of the financial function asks for a link to monitor supply chain risk and supply chain performance. Setting up KPIs aligned with the supply chain and finance function approach, enables to monitor the sustainability of KPIs by both functions, whereas finance has the first time internal knowledge of the supply chain. This gives the CFO a better insight over risks and the opportunity to deal with or communicate these risks to the stakeholders. Ernst & Young sees strong requests from the finance side for supply chain event management and a lot of opportunities associated. As markets change and topics like cost reduction and cash gain more and more importance on the agenda, an even stronger request for these systems will be recognized.

A Personal Field Report

Supply Chain Event Management & Strategic Networking

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Introduction

I would like to share with you 30 plus years of global exposure and experience within the industry and consulting including creating architectures as well as buying and selling business process outsourcing solutions around the world. In these years, I encountered many circumstances and business cases on the subject of Supply Chain Event Management (SCEM).

Since you as a reader already qualify as a subject matter expert within your fields of expertise by buying this book, I really do not want to bother you with a long story or theoretical ideas, but rather provide you with real life experiences that should help you reduce costs and risks and increase opportunities and value.

Therefore, I will come straight to the point(s) which hopefully will be of value to you as a reader of this book.

I personally think that SCEM plays an important role in an overall global business context.

In times of globalization, regional and global value chains have been a reality for years already. Given this, your organization has already achieved cost benefits in some areas but – at the same time – is exposed to various new threats and events, some of them expected and some of them not.

SCEM is important within internal organizations, outside of every organization as far as stakeholders and suppliers are concerned, and in between every organization's business units.

Interactions within virtual supply chains are effected at more or less every junction where events take place. This is even more important if you operate within a multilateral cascade and multilateral virtual web supply chain structure.

In many cases, you can see a combination of virtual value chain cluster structures where companies have developed network change management scenarios to anticipate events that might take place throughout the value chain(s) and cluster structures or at an isolated area within the supply chain cluster structure.

However, where should you focus your efforts to stop events from being a threat to your organization and supply chain now and in the future?

There are various elements and constructs that should be embedded in considerations and discussions surrounding the best value chain structures or future desired structures. The question is often whether the process architecture or the applied technology that might change, drive, and support the processes is the most important driver in the decision making process or are the people of your organization and business process architectures that are performing the various tasks throughout the value chain the drivers.

Whether the business model has its basis on the delivery of goods or services, the key is to balance people's expectations, processes, technology, cultures, events, and many other elements. Unfortunately, they cannot be seen in an isolated way. Each part of these elements is interrelated. A holistic meta strategy is required which combines classical elements of strategic intelligence and scenario management as well as many soft elements such as cultures and history, perceptions and expectations, the current state of the organization, and political or religious trends. Failing to include all of these elements as well as to manage and anticipate present and futures changes will result in failure or disruption of the value chains with various unpleasant impacts.

How do you want to proactively manage, anticipate, and/or react to events within the supply chain? Do you have pre-defined escalation procedures for crisis management and communication? How and how fast would you be capable of re-channeling routes of goods and services in the case of an emergency? What is your business continuation plan for the events that might take place throughout the value generation process?

Furthermore, the supply chains are not chains at all, but interconnected, evolving, dynamic network clusters. Therefore, a strategy which includes strategic networking is required. What is needed is a flexible, agile network strategy, which allows for modifiable responses in case events take place.

So, what is an event?

An event is an irregularity within the value chain embedded within a network cluster that requires responsible leadership action to ensure that operations continue.

The events that can take place are indefinite. They can be homemade via an inconsistent value chain or non-harmonious network clusters. They can be people, processes, technologies, or environmental stimuli. These events can be created internally or externally. They can have a positive reason or route (improvement) or a negative one (hurricane, terrorist attack).

As part of your risk management strategy in relation to the overall meta strategy, you might have already identified some of your critical nodes and anticipated event locations where events might occur which have a potentially devastating effect on your value chain if not managed in a proper way.

Constant change requires at least quarterly review and, if necessary, adjustment of the meta strategy for the future desired value chain structure. Such supply chain structures are needed for global coordination of global business units.

This requires a multifunctional, multiculturally experienced, and interculturally sensitive global project management and coordination team. It is crucial that the global team is balanced and includes people from various parts of the world. All important functions need representation due to the fact that many critical functions are effected by these value chain network structures governed by democratic principles.

You can compare this with the workings of a clock. If one cog does not work, it might stop the whole system. Therefore, it would be wise not to optimize everything from an end-to-end process perspective and instead consider the risks and business continuation within the future desired value chain structures and networks.

As part of good corporate governance, special governance or an internal audit would be required to review and observe strategy as well as the meta project team participants, project progression, implementation, transformation, and transition as well as the operations of these projects.

If something goes wrong, the investment for contingency planning will be by far lower than if the entire value chain comes to a standstill. Organization networks need early warning systems that are able to scan the dynamic network clusters on an ongoing basis.

Technology alone will fail to do it. Technology might be an enabler and technology might indicate deviations from mainstream measurements, but that is it. You need leadership at the operational level to ensure professional signals to the top management level and joint decision making while listening to the subject matter experts and taking their arguments into consideration. Process description might support adequately in day-to-day business, but in the case of a crisis exactly this case might not have been covered.

Proper processes are essential. Unfortunately, purely process driven management which tries to optimize the supply chains purely from a process perspective might put so much focus on the current processes instead of including technology and people’s opinions that any future change will make adjustments expensive and time consuming. The short-term benefits for today will be at the expense of the future. An amalgam of scenario planning, process intelligence and strategic networking is needed.

Strategy Development with SCEM in Network Structures

Although SCEM is only one element of a good overall strategy, it is an extremely important part of the strategy development process. A strategy not including this element will fail. Quarterly strategic reviews are necessary to comply with internal and external compliance regulations. It is wise for any corporation operating on a global scale to use regulatory requirements in order to improve their competitive position and add value from better controlling and higher transparency.

However, there is one catch. All of these initiatives will not work if remuneration systems and structures will only benefit in country management focus the achievement of any economic value added (EVA) or earnings before interest & tax (EBIT) targets. Therefore, companies should create additional or integrated bonus schemes for value clusters and supply chain value creation within the virtual or real value supply chains. The value contribution of each part should be made fully transparent for everyone to give all involved parties the feeling that the remuneration system and structure versus the value contribution is fair. This additional bonus scheme needs to be communicated in a proper, transparent way to allow for a full understanding of the potential future areas for which process and value contributions are desired.

Furthermore, strategic skill development programs and coaching are needed within the value clusters and value networks to allow for the desired outcomes. Full 360-degree feedback in all directions in addition to continued mapping of positive and negative gravitation fields are necessary. Even during the strategy development process, complementary functions such as marketing & sales, finance, tax, legal, and corporate communication should be present in these strategy workshops and be an active part in project design, business process architecture as well as the networks that should be used in the future.

The coordinator should be able to understand the interconnections between the various departments and should be an expert in intercultural communication. He/she should be able to manage and make the project sessions as attractive as possible for all involved parties to ensure involvement and engagement not only during the development, but especially when the strategy becomes operational.

Good measures should be implemented to ensure quality including at least quarterly review meetings to adjust and reposition these dynamic value clusters as the business continues to evolve into new markets, products, and services. Cannibalization between clusters and dysfunctional behavior of individuals would need to be immediately sanctioned by the corporate governance bodies. Inefficient and ineffective participating network clusters would have to be to be separated quickly if they contribute to the dysfunction of the overall process. One bad apple spoils the bunch.

If you consider and apply these steps, the chances of success increase substantially.

Business Process Reengineering with Networks

Strategic networking is a good way to create a flexible dynamic business process value chain and architecture and to reengineer your business processes within and via managed network clusters in order to reduce the impact of events.

You can create all kinds of networks of operational and knowledge pools that you need at any time. The only things you need to keep in mind are a people orientated management as well as the human connections you need to identify and maintain the functioning of these clusters on a continuous basis.

Always keep in mind that when you are talking about networks, that you are talking about people. These people might be within the networks, developing the technological architecture, or managing the people and networks. If you fail to manage the expectations of the involved people clusters you or the cluster of people that should be working together in the future and interacting with the new cluster, you have a problem.

Human resources should be brought in at an early stage in order to guide the human interactions within the network structures. Otherwise, personal dislikes and power battles may build up internally. People matching strategies are needed. Otherwise, you might face additional cannibalization wars within your structures, networks, and value chains.

Make sure you hire people that have soft skill capabilities, knowledge sharing capacities and know-how.

Leadership must be responsible and function as a role model for the whole organization. You reduce negative events volume in advance by managing your people in a positive way. Many events which could become disruptive to a corporate network supply chain are, in many cases, recognized by your people long in advance. Management has to listen to them and make according changes quickly to show the leadership commitment to them. Once you gain peoples trust, they will continue to report risks and opportunities.

Make sure the people who drive innovation and improvements within the networks and value chain clusters are getting a fair portion of the benefits generated. Human systems and networks in your organizations are highly intelligent, more intelligent then you may think or assume. The value creation and secure virtual value chains and network worlds are a direct result of good people management as part of these meta projects.

Every organization that plans to reengineer their business needs to keep in mind that the continuation of revenue streams is the most important thing. You need to keep this in mind as you plan your reengineering efforts. Do not try to do too many things at once. You need a step-by-step approach, slowly adjusting your business processes, value chains, and network clusters. Think in advance about new strategic alliances, potential mergers and spin offs within your business, new strategic alliances, and much more.

The events you are trying to get under control might control you if you do not progress very carefully. Never forget that you are impacting on networks. Picture a spider web and think what would happen if you tried to rip a piece of the web with your hand. The whole web net structure would be destabilized. So, tactically you need be very careful in your efforts.

However, if you do it right, including the development of proper escalation and clear communication protocols, you will succeed and get most of the potential events within your supply chain under control and potentially use them to your benefit.

Error Detection, Spread of Error Distribution, and Business Continuation within Supply Chain Networks

Prevention

As with every risk related initiative, risk prevention is always the best method to reduce damage and enhance cooperation for value creation.

Scenario Planning

Your organization should have a clear visualization of all critical SCEMs. Any ongoing change needs to be monitored constantly to see events that need to be changed or which require action by management.

Dynamic Strategy Adjustments

Your strategy should be adjusted on an ongoing basis. Find even just a few potential event examples that might happen in your supply chains. Direct or indirect suppliers network failure, natural disasters, power failure, human failure, strikes, sabotage, energy down times, new legal/compliance regulations, and potential terrorist attacks are just a few examples.

Error Cascade Impacts

The problem with the events is that they normally spread like a virus in speed and intensity depending on the node within the network(s). The variation detection and response evaluation and execution times are critical elements for protection and limitation of the damage or the implementation of an improvement.

Business Continuation

SCEM should be part of the overall business continuation and emergency plan for the organization, all value chains within the organization, and the connections to external supplier clusters.

Lessons Learned and Future Value from Vents within Your Value and Supply Chains

Every event, even a negative one, contains the seed of an even larger opportunity to improve your value chains. Do you keep track of your failures and turn them into good investments? If not, you should start doing so immediately. It might be that you are already sitting on valuable intellectual property, future profits, and a positive future cash flow.

Leadership is required that encourages employees to report events and errors (i.e. lessons learned) and makes transparent why this is beneficial for everyone. People who report errors (and, thus, areas needing improvement in order to stay competitive) should receive positive recognition in line with the gratification system of the culture and country from which this information originates.

Outlook

Events cannot be avoided within regional, continental, or global supply chains and clusters. However, if SCEM becomes an integral part of the overall strategy development, neither the process of change nor interruptions would be able to destabilize the entire organization or systems.

Global, decentralized cluster management with a global coordination center is the key. The supply chain event cluster management needs to be on the same knowledge level. If possible, the systems need to include artificial intelligence to identify errors that may be hidden from normal brain capacities. Nevertheless, humans should make the final checks and decisions.

Each critical cluster should be able to be easily switched to a new structure depending on the intensity of the event that might impact the supply chain structure. One sub network failure should not be capable of infecting the entire supply chain.

Events need to be analyzed on a continuing basis as they might be a signal for a trend change. Therefore, I would encourage you not to focus on the events, but instead to try to anticipate the upcoming events to the greatest extent possible.

I wish you all much success in you endeavors to create a functional SCEM structure that enables a proper network cluster management.

List of Abbreviations

AoG	Aircraft on Ground
API	Application Programming Interface
APS	Advanced Planning Systems
ARIS	Architektur integrierter Informationssysteme
BAM	Business Activity Monitoring
BI	Business Intelligence
BPEL4WS	Business Process Execution Language for Web Services
BPM	Business Process Management
BPEL	Business Process Execution Language
BPMI	Business Process Management Initiative
BPMS	Business Process Management Systems
BPM tools	Business Process Modelling tools
BPO	Business Process Optimization
BPR	Business Process Reengineering
BSC	Balanced Scorecard
B2B	Business to Business
CCES	Center for Computational Engineering Science
CME	Computational Materials Engineering
CPI	Collaborative Performance Indicator
CRM	Customer Relationship-Management
CSCW	Computer Supported Cooperative Work
C2B	Customer to Business
EAI	Enterprise Application integration
E-Commerce	Electronic Commerce
EDV	Elektronische Datenverarbeitung
E-Mail	Electronic Mail
ERP	Enterprise Resource Planning
et al.	et alii
etc.	et cetera
GPS	Global Positioning System
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communication
GUI	Graphical User Interface
HTML	Hypertext Mark up Language
HTTP	Hypertext Transfer Protocol
IT	Information Technology
IEC	International Electrotechnical Commission

ISO	International Standards Organization
J2EE	Java 2 Platform, Enterprise Edition
JiT	Just in Time
KPI	Key Performance Indicator
LBS	Location Based Services
LLP	Lead Logistics Provider
LRU	Line Replaceable Units
M-Commerce	Mobile Commerce
MES	Manufacturing Execution System
MRO	Maintenance Repair Overhaul
MSCEM	Mobile Supply Chain Event Management
NME	Novo-Nordisk-Engineering
PC	Personal Computer
PDA	Personal Digital Assistant
PIN	Personal Identification Number
PPS	Produktionsplanung und -steuerung
REFA	Verband für Arbeitsstudien und Betriebsorganisation
RFID	Radio Frequency Identification
SCEM	Supply Chain Event Management
SCM	Supply Chain Management
SME	Small and Medium Enterprises
SNM	Supply Network Management
SCC	Supply Chain Controlling
SCD	Supply Chain Design
SCOR	Supply Chain Operation Reference-Model
SOA	Service Oriented Architecture
SRM	Supply Relationship Management
TAM	Technology Acceptance Model
TQM	Total Quality Management
T&T	Tracking & Tracing
UbiCom	Ubiquitous-Computing
UDDI	Universal Description, Discovery, and Integration
UMTS	Universal Mobile Telecommunications System
URL	Uniform Resource Locator
VE	Virtual Enterprise
WLAN	Wireless LAN
WML	Wireless Markup Language
WSDL	Web Service Definition Language
VE	Virtual Enterprise
WWW	World Wide Web
XML	Extensible Mark-up Language

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Kurt Wiener (born in 1968), Managing Director of the EMPRISE Process Management GmbH since 2002, is a leading authority in Business Process Management. He is specialized in the conception of BPM solutions. Kurt Wiener founded PIKOS GmbH, a technology start-up company, October 2002 in Berlin. In July of 2005 he sold PIKOS to Hamburg's EMPRISE AG and is now Managing Director in the newly formed EMPRISE Process Management GmbH. In his career, Kurt Wiener's ambitious determination helped him to reach his leadership position. While studying economics at the University of Paderborn, Technical University of Berlin and UC Berkeley, he was already active as a Junior Consultant for the consulting company KPMG. After his studies he led a wide range of BPM projects as a senior Consultant for PRO UBIS GmbH. He was also the VP of IntraWare's BPM Business Unit where he managed the Berlin subsidiary and directed the expansion of the BPM activities for IntraWare.

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